# FACTORS AFFECTING THE DEVELOPMENT OF UNDERGRADUATE MEDICAL STUDENTS' CLINICAL REASONING ABILITY

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# THESIS ABSTRACT

It is important for doctors to be clinically competent and this clinical competence is influenced by their clinical reasoning ability. Most research in this area has focussed on clinical reasoning ability measured in a problem-solving context. For this study, clinical reasoning is described as the process of working through a clinical problem which is distinct from a clinical problem solving approach that focuses more on the outcome of a correct diagnosis. Although the research literature into clinical problem solving and clinical reasoning is extensive, little is known about how undergraduate medical students develop their clinical reasoning ability. Evidence to support the validity of existing measures of undergraduate medical student clinical reasoning is limited. In order better to train medical students to become competent doctors, further investigation into the development of clinical reasoning and its measurement is necessary. Therefore, this study explored the development of medical students' clinical reasoning ability as they progressed through the first two years of a student-directed undergraduate problem-based learning (PBL) program. The relationships between clinical reasoning, knowledge base, critical thinking ability and learning approach were also explored.

Instruments to measure clinical reasoning and critical thinking ability were developed, validated and used to collect data. This study used both qualitative and quantitative approaches to investigate the development of students' clinical reasoning ability over the first two years of the undergraduate medical program, and the factors that may impact upon this process. 113 students participated in this two-year study and a subset sample ($N = 5$) was investigated intensively as part of the longtitudinal qualitative research.

The clinical reasoning instrument had good internal consistency (Cronbach alpha coefficient 0.94 for $N = 145$), inter-rater reliability ($r = 0.84$, $p < 0.05$), and intra-rater reliability ($r = 0.81$, $p < 0.01$) when used with undergraduate medical students. When the instrument designed to measure critical thinking ability was tested with two consecutive first year medical student cohorts (N = 129, N = 104) and one first year science student cohort (N = 92), the Cronbach Alpha coefficient was 0.23, 0.45 and 0.67 respectively.

Students’ scores for clinical reasoning ability on the instrument designed as part of this research were consistent with the qualitative data reported in the case studies. The relationships between clinical reasoning, critical thinking ability, and approach to learning as measured through the instruments were unable to be defined. However, knowledge level and the ability to apply this knowledge did correlate with clinical reasoning ability. Five student-related factors extrapolated from the case study data that influenced the development of clinical reasoning were (1) reflecting upon the modeling of clinical reasoning, (2) practising clinical reasoning, (3) critical thinking about clinical reasoning, (4) acquiring knowledge for clinical reasoning and (5) the approach to learning for clinical reasoning.

This study explored students’ clinical reasoning development over only the first two years of medical school. Using the clinical reasoning instrument with students in later years of the medical program could validate this instrument further. The tool used to measure students’ critical thinking ability had some psychometric weaknesses and more work is needed to develop and validate a critical thinking instrument for the medical program context. This study has identified factors contributing to clinical reasoning ability development, but further investigation is necessary to explore how and to what extent factors identified in this study and other qualities impact on the development of reasoning, and the implications this has for medical training.

## CERTIFICATION OF THE THESIS ORIGINALITY

This thesis includes no material that has been awarded a degree or diploma from any institution and, to the best of my knowledge, includes no material published or written by anyone else, except where due reference has been documented.

I give consent for this copy of my work, when put in the University Library, to be made available in all forms of media.

Signature: …………………………………………… Date………………...

Kirsty Anderson

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# CHAPTER ONE - AN OVERVIEW OF THIS STUDY

## 1.1 THE BACKGROUND AND RATIONALE FOR THIS STUDY

With advances in science and technology over the past century, some of the attributes and skills required for being a doctor have changed. Historically, traditional medical curricula involved a number of years of basic science education and then further years of training in a clinical setting. With increasing pressure for the cost of educating medical students to be economical, reflection upon the specific competencies required of doctors and the best way for students to achieve these competencies occurred (Elstein, Schulman and Sprafka, 1978). The ability of doctors to solve clinical problems was seen to be of paramount importance, and recommendations were made that medical students needed to become adept at the process of clinical problem solving, not just demonstrate that they had learnt basic science information and clinical skills (Elstein et al., 1978). This stimulated much research into how doctors solved clinical problems and what education was necessary for students to achieve this skill. The relevance of students learning vast basic science knowledge in a discipline-centred way and only then being taught a generic set of problem solving skills, as may occur in traditional medical curricula, had also been questioned. This gave rise to reform in the 1950s when students began to be taught basic science in an organ-system-centred approach (Kendall and Reader, 1988). In the 1960s and 70s, reform continued when in an effort to teach students how to use their knowledge to solve clinical problems, some medical curricula changed to a problem-based learning (PBL) format (Neufeld and Barrows, 1974). With the ability to solve clinical problems being seen as crucial to a doctor’s clinical competence, assessment of medical students’ clinical problem solving ability rather than just basic science knowledge became necessary.

All of the major reviews of medical education report on the need for the demonstration of clinical competence, which involves clinical problem solving ability (Australian Medical Council, 2002; The Royal College of Physicians and Surgeons of Canada, 1996; General Medical Council, 1993; Association of American Medical Colleges, 1998). Thus two categories of research into clinical problem solving have continued until today. Firstly, there has been an investigation of the process of clinical problem solving, partly in an effort to better understand how to teach medical students to gain this ability. This has involved much consideration of the way in which learning occurs, how knowledge is stored and accessed for clinical problem solving and the best way to teach medical students to solve clinical problems. Measuring clinical problem solving ability has proved to be difficult and thus a second category of research has been devoted to devising methods of assessing this entity. In a litigious age, with a world of people likely to work in a number of places during their lifetime, the need for valid, reliable and time-efficient measures of doctors' clinical problem solving ability at a local, national and international level has never been greater.

Solving clinical problems or making a diagnosis is often referred to as clinical reasoning. The underlying assumption is that correctly solving a clinical problem or making the diagnosis can only be achieved through clinical reasoning, but in reality this end point also can be reached by guesswork or other methods that do not involve reasoning. Clinical reasoning is a complex concept that is more encompassing than clinical problem solving, so confusion arises when these terms are used interchangeably (Groves, O'Rourke and Alexander, 2003a and 2003b; Higgs and Jones, 2000). Many attempts have been made to develop measures of clinical reasoning ability, but in reality most of these instruments only measure the endpoint of this process which is clinical problem solving ability. Clinical problem solving has been described as commencing with a patient's presentation, making multiple hypotheses about the diagnosis of the patient's problem and pursuing an hypothesis-orientated enquiry, then synthesising the problem and making a diagnostic decision before ordering laboratory tests and making management decisions (Barrows and Tamblyn, 1980). There is no reported distinctive definition of clinical reasoning even after 30 years of research investigating elements of clinical problem solving, which suggests that it is a complex concept.

Clinical reasoning involves integrating and applying different types of knowledge, using numerous types of reasoning, critically thinking about arguments and reflecting upon the process used to arrive at a diagnosis. Clinically reasoning through a case may result in the correct solution to the problem, but this process is primarily concerned with working through explanations for the symptoms, signs and investigation results presented. Knowledge databases useful for clinical reasoning may take the form of basic science, understanding the relative weightings of key features in a case, knowing the likelihood or probability of diseases in particular groups of people and understanding the presentation of diseases and their natural history. Depending on the elaboration of an individual's knowledge base, different types of reasoning (hypothetico-deductive, forward reasoning, case based reasoning and scheme inductive reasoning; all discussed further in section 2.3) may be applied to explain the symptoms and signs of a new case. It is the intricate linking of all of these processes that constitutes the meshed network of clinical reasoning.

Although it is difficult to precisely characterise the process of clinical reasoning, a working definition is needed in order to study this entity with undergraduate medical students. In this thesis, the term clinical reasoning will refer to the processes of:

- analysing information in a clinical case,
- identifying the relative significance of the details given,
- hypothesising mechanisms for the symptoms, signs and investigation results detailed by applying relevant prior knowledge to this particular case,
- discussing ideas in a logical manner,
- supporting individual steps in the reasoning process with relevant findings and specific information,
- asking questions to clarify particulars/details within the case,
- identifying areas where further knowledge is required,
- re-evaluating learning priorities in response to new information/discussion and
- summarising reasoning and evidence for the working hypothesis and distinguishing it from competing/alternative hypotheses.

There are few investigations of clinical reasoning reported in the literature. Little is known about the development of this ability or factors that may impact upon this process, although it is accepted that knowledge is necessary for clinical reasoning.

The University of Adelaide Medical School encourages students to simultaneously develop their knowledge bases and clinical reasoning ability in a graduated manner. This practice is promoted by assessment that specifically tests for both knowledge and reasoning, and by the integrated, student-directed, problem-based learning curriculum. When students begin at the school, they are encouraged to pursue a hypothetico-deductive approach to reasoning and to use reasoning through cases as a stimulus for gradually developing and utilizing their knowledge bases. Students' knowledge bases become elaborated as they apply what they learn, using it to reason through increasingly complex cases. As students' knowledge bases develop, they are gradually introduced to using their knowledge with more expert approaches to reasoning and diagnosis. This unique curriculum provides an environment in which to investigate the process of clinical reasoning and factors that impact upon its development.

## 1.2 THE PURPOSE OF THIS STUDY

Therefore, the primary aim of this study was to gain insight into the development of clinical reasoning ability by studying a group of undergraduate first and second year medical students. This study particularly focused on establishing what influence critical thinking ability, knowledge base and approach to learning had on the development of clinical reasoning in this context.

## 1.3 THE RESEARCH QUESTIONS

The seven research questions investigated as part of this study were:

1. How can student clinical reasoning ability be measured?
2. How do students' clinical reasoning abilities change as they progress through the program?
3. What factors influence the development of student clinical reasoning ability?
4. How can students' critical thinking ability be measured?
5. How do students' critical thinking abilities influence their clinical reasoning?
6. How do students' knowledge bases influence their clinical reasoning?
7. How do students' approaches to learning influence their clinical reasoning?

## 1.4 THE SIGNIFICANCE OF THIS STUDY

The findings of this study will be of benefit to medical educators, medical education programs and to the medical students who participate in these programs. This study furthers our understanding of the complexity of clinical reasoning, not just the endpoint of this process which actually describes clinical problem-solving. For medical program planners, this will contribute to knowing how curriculum delivery should be modified to assist students better to develop their clinical reasoning ability. The designing of an instrument to measure clinical reasoning provides an opportunity to assess students' development of this ability in a medical program. The clinical reasoning instrument designed in this study may provide medical educators with a model for re-considering the approach used to assess reasoning in an undergraduate medical curriculum. For medical students, the development of an instrument which measures their clinical reasoning ability provides the opportunity to receive formative feedback and diagnostic information about which components of clinical reasoning they need to improve.

Overall, insight into the factors that enhance or limit students' clinical reasoning development may contribute to changes in medical curricula planning and implementation. This, in turn, may provide students with better opportunities to develop clinical reasoning and become clinically competent doctors.

## 1.5 AN OUTLINE OF THIS THESIS

In Chapter Two, a review of the literature about clinical reasoning within the historical context of clinical problem solving research is presented, and factors that may influence clinical reasoning development, such as a person's knowledge base, critical thinking ability and approach to learning, are highlighted. A review of the methods used to measure some of the entities in this study is also given. Finally, the particular research questions that this study addresses are outlined. In Chapter Three, the rationale for employing both qualitative and quantitative measures to investigate the development of clinical reasoning is provided. The context in which this study was conducted is described and the ethical issues involved in this research are considered. The methodology of the study is outlined, including an explanation of the instruments used to measure clinical reasoning and three factors hypothesised to impact upon its development, namely critical thinking, knowledge base and approaches to learning. Chapter Four details the development of an instrument to measure clinical reasoning, explains the administration of this instrument and describes how the results thereby obtained were analysed. Chapter Five details the development of an instrument to measure critical thinking, explains the administration of this instrument and also outlines how the yielded results were used. Chapter Six describes the case studies involved in this project, including a detailed description of the case study selection process and the methods used to collect these data. The case study results are then discussed with the additional study findings in Chapter Seven. Finally, in Chapter Eight, answers to the research questions are summarised, limitations of the study assessed and recommendations for further research described.

# CHAPTER TWO - THE LITERATURE REVIEW

## 2.1 INTRODUCTION

As explained in Chapter One, clinical reasoning research has largely focused on the study of clinical problem solving. Therefore, this chapter critically reviews the research into clinical problem solving and clinical reasoning. This chapter also highlights three factors that may impact on the development of clinical reasoning ability, outlines the gaps in knowledge about this entity and then concludes by delineating areas that require further study.

## 2.2 FROM NOVICE TO EXPERT CLINICAL PROBLEM SOLVING

Medical education involves helping students to become clinically competent and able to solve clinical problems. In order to determine how best to help students achieve these goals, it is clear that it is necessary to understand how a person progresses from being a novice to an expert clinical problem solver. Thus, a focus of early research in this area became the comparison of the clinical problem solving processes of experts (doctors) with those of novices (medical students) (Barrows and Bennett, 1972; Chi, Feltovich and Glaser, 1981; Dreyfus and Dreyfus, 1984; Simon and Chase, 1973; Elstein, Schulman, Kagan, Jason and Loupe, 1972; Elstein et al., 1978; Neufeld, Norman, Feightner and Barrows, 1981). The underlying premises for this early research were that 1) solving a clinical problem correctly was the result of using sound clinical reasoning, 2) clinical problem solving involved engaging a set of skills that experts (doctors) had learned but novices (new medical students) did not yet possess, and 3) an understanding of how doctors solved clinical problems would provide information on how to teach medical students to do the same (Kassirer and Gorry, 1978). Therefore, this initial research concentrated on investigating the nature of clinical problem solving skills.

### 2.2.1 Background Research

Observational studies into the reasoning used by experts to solve clinical problems have been carried out by numerous researchers using standardised patients (Barrows and Bennett, 1972; Elstein et al., 1972; Elstein et al., 1978; Neufeld et al., 1981). Albeit in a small study, Barrows and Bennett (1972) demonstrated that in an effort to solve clinical problems, doctors developed and then reasoned through diagnostic hypotheses by pursuing inquiry-orientated questions to confirm or refute their hypotheses. These researchers asked 6 neurology residents to recall their reasoning during an interaction with a standardised patient, providing a videotape of the subject's interaction with the standardised patient to stimulate their memories (Barrows and Bennett, 1972).

Further investigation into the reasoning used by expert subjects to solve clinical problems led Elstein et al. (1972) to conclude that it involved four processes: cue acquisition, hypothesis generation, cue interpretation and hypothesis evaluation (Elstein et al., 1972). Elstein et al.'s study investigated the clinical problem solving process used by 25 expert physicians at Michigan State University using simulated and paper case patients and the clinicians speaking out loud as they worked. The physicians generated 3-5 specific diagnostic hypotheses before they had gathered most data. These hypotheses emerged from the physicians' background knowledge of medicine and range of specific clinical experiences, as well as the problematic elements discovered in the early stages of their encounter with the patient. From this investigation, Elstein et al. concluded that hypothesis generation involved attending to initially available clues, identifying problematic elements from among these cues, associating from problematic elements to long-term memory and back, generating hypotheses and suggestions for further inquiry, and informally ranking hypotheses according to the physician's subjective estimates. Furthermore, Elstein et al. found that clinicians not only systematically searched for data and inquired for further information that would confirm or refute their hypotheses, but also created opportunities to obtain new information that may have led to other hypotheses (Elstein et al., 1972).

Neufeld et al.'s (1981) study confirmed that reasoning was hypothetico-deductive in nature and not only did the doctors (expert clinical problem solvers) score higher than the students (novice clinical problem solvers), but students' scores were found to improve over time with increasing education in the biomedical sciences. A study by Elstein et al. (1978) involving encouraging observed physicians at Michigan State University to 'think aloud' their reasoning as they evaluated standardised patients demonstrated that experts had more extensive underlying knowledge. Neufeld et al.'s (1981) and Elstein et al.'s (1978) findings led to the conclusion that perhaps diagnostic accuracy was predominantly related to content knowledge, and not a set of generic clinical problem solving skills.

### 2.2.2 Knowledge and Clinical Problem Solving Expertise

Research in varying fields deemed expertise to be related to recall of knowledge in the area concerned. A review of the literature by Vicente and Wang (1998) revealed that there were at least 51 studies in 19 areas demonstrating that expertise is related to recall of information. The work of De Groot (1965) and Simon and Chase (1973) demonstrated that the ability to recall typical mid-game positions of chess pieces was related to one's level of expertise. Similarly, research done by psychologists Chi et al. (1981) on subjects' representations of physics problems and their ability to solve them, showed that experts with comparatively vaster physics knowledge were better at solving new physics problems than novices. Findings from research into computer programming expertise (Adelson, 1984; McKeithen et al., 1981) and bridge (Charness, 1979) were consistent with those of Simon and Chase (1973) and Chi et al. (1981), namely that expertise was related to recalling of knowledge in the same domain.

With this background understanding, some researchers in medicine began investigating the relationship between the ability to recall information (as a measure of knowledge) and clinical problem solving expertise (Claessen and Boshuizen, 1985; Coughlin and Patel, 1987; Groen and Patel, 1985; Norman, Brooks and Allen, 1989; Patel, Groen and Fredericson, 1986). However, in most of this research where doctors' (experts') recall of information was compared with students' (novices') recall, superior recall was not significantly associated with expertise. There was, however, an intermediate effect where although diagnostic accuracy increased in accordance with expertise, subjects of intermediate levels of expertise recalled case information better than expert or novice subjects (Gilhooly, McGeorge, Hunter, Rawles, Kirby, Green and Wynn, 1997). For example, a study of 92 subjects of increasing expertise required to diagnose and explain their reasoning for 4 case studies demonstrated that intermediate subjects applied more detailed and complete biomedical knowledge than the experts (Van der Weil, Boshuizen and Schmidt, 1994). These findings were supported by other studies (Boshuizen, 1996; Rikers, Schmidt and Boshuizen, 2000; Schmidt and Boshuizen, 1993a; Schmidt, Boshuizen and Hobus, 1988). It is therefore interesting to examine the outcomes of research focusing on 1) what type of knowledge influences problem solving, and 2) how the knowledge that is used for problem solving is organized.

#### *2.2.2.1 Biomedical Knowledge and Clinical Knowledge*

Several studies have challenged the perspective that problem solving ability was primarily related to the amount of an individual's biomedical knowledge, instead suggesting that it was actually primarily related to the amount of an individual's clinical knowledge (Bordage and Lemeiux, 1991; Boshuizen and Schmidt, 1992; Coderre, Mandin, Harasym and Fick 2003; Patel, Evans and Groen, 1989; Schmidt, Boshuizen and Hobus, 1988; Woloschuk, Harasym, Mandin and Jones, 2000). In medical schools, students' education often occurs in two phases, namely preclinical (at University, learning biomedical knowledge) and clinical (in hospitals, learning to apply this knowledge and diagnose illnesses). It was observed that although many students may have had vast biomedical knowledge, they struggled to solve real clinical problems (Nendaz and Bordage, 2002).

There has been much investigation into the relative impact of a person's level of biomedical and clinical knowledge on clinical problem solving expertise. Initial studies by Schmidt, Boshuizen and Hobus (1988) and Patel, Evans and Groen (1989) led to what has been named the "two-world hypothesis" (van de Weil, Boshuizen and Schmidt, 2000, p.327). In essence, this two-world hypothesis states that experts have both biomedical and clinical knowledge but use only the latter for solving clinical problems in their area of expertise (Rikers, Schmidt and Boshuizen, 2000). In an effort to understand how much clinical knowledge and biomedical knowledge contributed to diagnostic expertise, Patel, Evans and Groen (1989) studied the explanations for a paper clinical case of bacterial endocarditis given by researchers, doctors and medical students at 3 different levels in their studies. The student subjects attended McGill University where biomedical science was taught first, then clinical science, after which the students became interns and practised clinically. Therefore, Patel et al. had problem-solving subjects with a broad range of biomedical knowledge and clinical experience for comparison. No mention was made of how many subjects were involved in Patel et al.'s research, and therefore it is difficult to know the generalisability of these research findings. However, Patel et al. claimed that experts used clinical knowledge rather than biomedical knowledge to diagnose a patient's illness and only novices, who had no choice but to use biomedical knowledge, used this to reason clinically. Inferences novices made from the biomedical knowledge in order to solve clinical problems were reported as often being inconsistent and incorrect. Schmidt et al. (1988) also tested the diagnoses, explanatory reasoning and clinical information recall of subjects with differing levels of medical expertise after they had been presented with clinical cases. Findings from Schmidt et al.'s (1988) study were consistent with that of Patel et al. (1989): experts used clinical knowledge rather than biomedical knowledge to diagnose a patient's illness. Patel et al. and Schmidt et al. also concluded that using biomedical knowledge to diagnose a patient's illness tended to be a characteristic of novice reasoning.

Boshuizen and Schmidt (1992) further explored the role of biomedical knowledge in the diagnosis of clinical cases by presenting four subjects of different clinical expertise levels (a 2nd year, 4th year and 5th year medical student and a family physician of 4 years training) with online information about a pancreatitis case. The researchers then analysed the think aloud reasoning of these subjects, including noting subjects' use of biomedical and clinical knowledge as they worked through the case, and concluded that experts did not use overt biomedical reasoning to solve the clinical problem (Boshuizen and Schmidt, 1992). This study was repeated with a total of 20 subjects of different clinical expertise levels: six 2nd year, four 4th year, five 5th year medical students and 5 family physicians with 4 years experience (Boshuizen and Schmidt, 1992). The subjects were to think aloud their reasoning for the pancreatitis case and then describe in written form the pathophysiological processes underlying the disease. The data were analyzed to test why the experts did not use overt biomedical reasoning to solve the clinical problem (Boshuizen and Schmidt, 1992). Although their study had a small number of subjects and a narrow range of diagnostic tasks, Boshuizen and Schmidt (supported by evidence from other investigations), reached a different conclusion from that of Patel et al. (1989). Experts (doctors) did use biomedical knowledge to solve clinical problems in two ways, namely (1) when solving clinical problems within their areas of expertise, doctors' biomedical knowledge had a tacit role as it was found to be "encapsulated" and integrated into clinical knowledge, and (2) when solving clinical problems outside of their area of expertise, doctors used overt biomedical knowledge to reason through the case (Boshuizen and Schmidt, 1992, p. 179; Patel et al., 1989). The conclusion that doctors use biomedical knowledge in two ways to solve medical problems has been substantiated by more recent studies (deBruin, Schmidt and Rikers, 2005; Rikers, Loyens, Te Winkel, Schmidt and Sins, 2005; Rikers, Schmidt and Boshuizen 2002; Rikers, Schmidt and Boshuizen, 2000; Rikers, Schmidt, Boshuizen, Linssen, Wesseling and Paas, 2002; Schmidt and Boshuizen, 1993a and 1993b; van de Weil, Boshuizen and Schmidt, 2000).

#### *2.2.2.2 Knowledge Organisation*

Other research has explored the hypothesis that expertise in clinical problem solving is related not primarily to the amount of knowledge or the type of knowledge (biomedical versus clinical) a person has, but rather to the way in which the person's knowledge is encapsulated or interlinked and stored (Beck and Bergman, 1986; Boshuizen and Schmidt, 1992; Custers, Boshuizen and Schmidt, 1996; Patel et al., 1989; Rikers et al., 2002; Rikers et al., 2002; Schmidt and Boshuizen, 1993a and 1993b; van de Weil et al., 2000). Preliminary work by Grant and Marsden (1987) found that there were marked differences in the precise structure and content of thought (of case interpretation and forceful features, i.e. the use of crucial pieces of information that influenced reasoning) between expert and novice clinicians, but no difference in the breadth of thought (i.e. number of diagnoses or number of forceful features). Grant and Marsden (1987) presented participants with different amounts of clinical experience (e.g. consultants, registrars, senior house officers, and first and third year medical students) with case histories. All subjects were asked to generate diagnostic hypotheses (solutions) for the clinical problems and to identify the pieces of information (forceful features) that gave rise to their diagnoses (Grant and Marsden, 1987). Schmidt, Norman and Boshuizen (1990) proposed that doctors' knowledge was organized into basic mechanisms of disease, illness scripts and examples of cases derived from previous experience (Schmidt et al., 1990). They also hypothesised that elaborating medical knowledge (clinical findings, anatomic locations, pathophysiologic explanations and disease taxonomies), compiling it into networks (encapsulated, higher order knowledge structures), linking abridged networks (into a scheme of relationships and diagnoses), and forming illness scripts helped in arriving at a correct diagnosis for complex clinical cases

(Schmidt et al., 1990). Schmidt et al. (1990) hypothesized that the clinical problem solving ability of novices (medical students), gradually increased as they progressed through medical school and internship, gaining the aforementioned knowledge encapsulation.

Bordage and Lemieux (1991) investigated the hypothesis of knowledge encapsulation and reported that having reduced knowledge (small amounts of information), or dispersed knowledge (long lists of static diagnoses originating from rote memorisation) caused difficulties for all participants when solving clinical problems, but that expert clinical problem solvers put information into many organised structures. Bordage and Lemieux's (1991) study compared the organization of experts' and novices' knowledge structures using 39 subjects; 29 2$^{nd}$ Year medical students and 10 specialist doctors. The 2$^{nd}$ Year subjects had been randomly selected from tutorial groups of students based on whether the tutors had deemed them to be academically "strong" or "weak", so that there was variation amongst them to compare against expert clinical problem solvers (the specialists). Subjects were presented with up to 4 of 7 paper cases and asked to 'think aloud' their reasoning. The transcriptions of the subjects' reasoning, the number of distinct 'semantic axes' (a system of organising signs and symptoms according to relationships of abstract qualities) each used, and whether they had reached the correct diagnosis was analysed.

Bordage and Lemieux's (1991) results provided some evidence to support the argument that clinical problem solving expertise was related to knowledge encapsulation: in order to reason through new clinical cases expertly, knowledge needed to be banked in organised structures so that it could be easily retrieved and applied. Results from further studies supported this theory and added that sub-experts revert to using biomedical knowledge rather than encapsulated knowledge to solve clinical problems outside their area of expertise (Rikers, Schmidt and Boshuizen, 2002; Rikers, Schmidt, Boshuizen, Linssen, Wessling and Paas, 2002; Rikers, Schmidt and Moulaert, 2005).

Initially, Rikers, Schmidt and Boshuizen (2000) split 72 Maastricht University students of differing levels and 24 internists into three groups. These three groups of subjects were allocated different amounts of time to diagnose and explain four clinical cases. Under time pressure, experts' biomedical explanations for the cases were less extensive than those of advanced students', suggesting that they used primarily clinical knowledge to solve the clinical case. However, for the group given more time, experts' pathophysiological explanations were more elaborate that advanced students', intimating that the biomedical knowledge was present but encapsulated at a deep level, and not utilised unless needed or requested (Rikers et al., 2000). Further research into whether experts used biomedical knowledge for solving clinical problems in routine practice compared neurologists' (subexperts') and cardiologists' (experts') recall of information, diagnoses and pathophysiologial explanations for two clinical cardiology cases (Rikers, Schmidt and Boshuizen, 2002; Rikers, Schmidt and Moulaert, 2005). Cardiologists developed more accurate diagnoses and their explanations had more high-level inferences than those of the neurologists (Rikers, Schmidt and Boshuizen, 2002). A very similar study was done with cardiologists and pulmonologists, who each had to study four clinical cases, two of which were cardiovascular and two of which were respiratory in nature – thus testing the physicians both in and out of their domain of expertise (Rikers, Schmidt, Boshuizen, Linssen, Wesseling and Paas, 2002). Again, in their domain of expertise, the physicians developed more accurate diagnoses and their explanations had more high-level inferences than when outside their domain of expertise (Rikers, Schmidt, Boshuizen, Linssen, et al., 2002). In a similar study to the one reported earlier (see 2.2.2.1 Biomedical Knowledge, Clinical Knowledge and Clinical Problem Solving), Rikers, Schmidt and Moulaert (2005) compared the biomedical and diagnostic inferences used for clinical reasoning by 15 family physicians and 15 fourth year medical students at Maastricht University in the Netherlands using a lexical decision-making task with 80 computer clinical cases. Both students and physicians used biomedical and diagnostic inferences, but physicians were able to generate them faster and more accurately, suggesting that even with increasing expertise, biomedical knowledge is still used for reasoning through clinical problems (Rikers et al., 2005).

In summary, this research suggests that in order to solve clinical problems, experts use organized, or encapsulated, knowledge to reason clinically (Bordage and Lemieux, 1991; de Bruin et al., 2005; Rikers et al., 2000; Rikers et al., 2005; Schmidt et al., 1990). Experts may resort to using primarily biomedical knowledge to solve clinical problems outside their area of expertise (Rikers, Schmidt and Boshuizen, 2002; Rikers, Schmidt, Boshuizen, Linssen et al., 2002). However, the two key questions that remain are (1) how do novices progress from having biomedical knowledge to achieving this knowledge encapsulation and (2) exactly how does having encapsulated knowledge help novices to reason clinically?

#### *2.2.2.3 Knowledge Schemes*

One hypothesis in a recent review of the clinical problem solving expertise literature by Coderre, Mandin, Harasym and Fick (2003) was that knowledge schemes increased students' memory organization and enhanced diagnostic success. A scheme was defined as a decision-making tree, a framework around which students could base new learning and a tool they could use to reason diagnostically. Research into the use of schemes completed by Beck and Bergman (1986) and McLaughlin and Mandin (2002) suggested that they were a useful way to present information and encourage clinical problem solving. Beck and Bergman (1986) compared medical students' knowledge of paediatric cardiology when they solved three clinical cases and found that the problem solving skills of eighteen students who had been taught using schemes were better than seventeen others who had been taught in a format that was more textbook orientated. McLaughlin and Mandin (2002) reported that in first year medical students who were learning about metabolic alkalosis, using schemes had a positive influence on examination scores.

To test the theory that knowledge organised into schemes enhanced diagnostic success, the problem solving strategies of 20 gastroenterologists and 20 final year medical students at The University of Calgary were studied (Coderre et al., 2003). Subjects were asked to look at four clinical cases, answer questions on them and provide diagnoses. Two other diagnostic experts then interviewed the examinees and asked them to think aloud about how they derived each diagnosis. Based on the audiotaped and videotaped interview, the diagnostic experts made a judgment about whether the examinee's predominant method of solving clinical problems was pattern recognition, scheme-inductive reasoning or hypothetico-deductive reasoning. The premise was that these three clinical problem solving methods primarily relate to using illness scripts, knowledge schemes or overt biomedical knowledge to solve the clinical problem, respectively. Correlations between the two judges' initial diagnostic reasoning scores of the participants was 0.84 (Coderre et al., 2003). Coderre et al.'s (2003) study found that those subjects studied were 5 times more likely to arrive at the correct diagnosis if using schemes or illness scripts rather than overt biomedical knowledge to solve the clinical problem. The evidence suggests that one way novices can become expert problem solvers is by learning information in the form of schemes (Coderre et al., 2003).

However, research into the use of schemes has not investigated how they help students to learn to reason clinically through a new situation. Schemes are not content-independent as they are only useful for the situations where all circumstances are accounted for within the scheme. Also, in order to use the scheme one must already have the knowledge contained within it. This makes scheme-inductive reasoning difficult for relative novices such as medical students.

### 2.2.3 Section Summary

In summary, both the acquisition of knowledge and the way in which that knowledge is organised is important for solving clinical problems. It has been argued that the process of problem solving or clinical reasoning may be enhanced by developing encapsulated knowledge structures to apply in new situations. However, many of the studies reported in the literature review had small numbers of subjects, which limits the power of their findings. Also, few studies have focussed on the role of knowledge in the process of clinical reasoning rather than just the end point of clinical problem solving. Research into the problem solving ability of medical experts also identified that they may use different methods (for example hypothetico-deductive or scheme inductive reasoning) to solve clinical problems. However, few studies have explored how and to what extent these methods of clinical problem solving are involved in clinical reasoning.

## 2.3 TYPES OF REASONING USED BY EXPERTS

Investigation into clinical problem solving has identified some different forms of reasoning that may constitute the methods clinicians use to work through clinical cases. These methods include hypothetico-deductive reasoning, forward reasoning, case-based reasoning and scheme inductive reasoning.

### 2.3.1 Hypothetico-deductive Reasoning

Hypothetico-deductive reasoning was identified during the 1970s as a method used by clinicians to reason through cases (Barrows and Bennett, 1972; Elstein et al., 1978). This form of reasoning involves starting with an hypothesis (a statement about a situation that may be true or false) and then testing this hypothesis and modifying it as a consequence of the result of the test (Groen and Patel, 1985). Hypothetico-deductive reasoning is synonymous with predictive, causal or backward reasoning (Hmelo, Gotterer and Bransford, 1997). Using hypothetico-deductive reasoning is important for learning, as students have increased analogic transfer if they test hypotheses (Lewis and Anderson, 1985). Hypothetico-deductive reasoning can be utilised when an organised knowledge structure has not been developed, allowing diagnosis when medical problems are outside the area of expertise of the problem solver as it is a generic approach (Elstein et al., 1978; Hmelo et al., 1997; Rikers et al., 2005). Therefore it could be argued that students and doctors will have use for this form of reasoning throughout their careers: there will always be some clinical cases that lie outside one's area of expertise and previous experience.

### 2.3.2 Forward Reasoning

Experts have been reported to use forward (or data-driven) reasoning (Gilhooly, 1990; Hmelo et al., 1997; Patel and Groen, 1986). This form of reasoning involves making a chain of assumptions from patient data and thus refining one's diagnostic hypotheses. In 1986, Patel and Groen looked at the reasoning of 7 cardiologists. In this small study, subjects were given two and a half minutes to peruse a paper case of infective endocarditis (Patel and Groen, 1986). Analysis of the subjects' data recall, the pathophysiological hypotheses they detailed, and the diagnoses that they made revealed that 4 out of 7 of the subjects correctly diagnosed the patient's condition, and these 4 used forward reasoning compared with the backward reasoning used by the 3 subjects who incorrectly diagnosed the patient's condition. However, in order to use forward reasoning, one must have an expert's knowledge organization so that new patient data can be pattern matched with old cases. Thus forward reasoning is a less viable method for novices who are unlikely to have an adequate knowledge base.

### 2.3.3 Case-based Reasoning

Illness scripts are a concept borrowed from cognitive psychology and they were first applied in a medical context by Feltovich and Barrows (1984), and have been identified as one method of using knowledge to solve new cases (Feltovich and Barrows, 1984; Schmidt et al., 1990). The use of illness scripts to reach a diagnosis in a new clinical problem has been labelled 'pattern recognition' or 'case-based reasoning' as it can be described as matching a diagnosis from a previous clinical case to the new current case due to the cases having certain similarities (Coderre et al., 2003 p. 695; Eshach and Bitterman, 2003). However, although recognizing patterns may be a useful process for experts, novices have limited experience and knowledge from which to build a library of scripts that they can then safely use in order to reach a diagnosis in a new case.

### 2.3.4 Scheme Inductive Reasoning

Scheme inductive reasoning is based on schemes which when drawn on paper, are similar to road maps. The schemes reflect the way expert clinicians chunk information to store it in their memories and recover it to solve problems (Coderre et al., 2003). A scheme is "a mental categorisation of knowledge which contains a particular organised way of understanding and responding to a complex situation" (Woloschuk, Harasym, Mandin and Jones, 2000, p. 437). Solving clinical problems with scheme inductive reasoning involves using information from the patient (symptoms, signs, laboratory results) to differentiate between types of conditions at the intersections of the scheme and to therefore prefer one condition or the other depending upon the presence or absence of a clinical finding. However, although schemes may be useful for experts, novices have limited experience and knowledge from which to build schemes that they can then safely use in order to reach a diagnosis in a new case.

### 2.3.5 Section Summary

There is evidence to suggest that different reasoning approaches exist, namely hypothetico-deductive reasoning, forward reasoning, case-based reasoning and scheme inductive reasoning. Doctors are likely to use many of these at different times depending upon the situation at hand. However, there is only limited research on the development of these forms of reasoning in medical students.

## 2.4 CLINICAL REASONING IN MEDICAL STUDENTS

Recent research into clinical reasoning in medical students has been focusing on the process itself, rather than its end point of diagnosis. Groves, O'Rourke and Alexander (2003a) investigated clinical reasoning by testing 21 general practitioners with 20 years experience and 78 medical students with Clinical Reasoning Problems (CRPs). High scores on CRPs depended on the identification and interpretation of relevant clinical information (or critical features), rather than correctly nominating a likely diagnosis (Groves et al., 2003b). This study examined the clinical reasoning process and concluded that amalgamating clinical data before generating hypotheses was not necessarily dependent on knowledge and that this was one of the most difficult clinical reasoning skills to master (Groves et al., 2003b). These researchers advocated further investigation into clinical reasoning to clarify this matter. The need for investigation of clinical reasoning was considered in 1971 when Helfer, Slater and Goltz emphasised the importance of measuring objectively and recording the diagnostic process and reported that

> *in the past we have emphasised the quality of the diagnosis or end product - that the diagnosis is made. In order better to prepare future physicians to solve clinical problems which are as yet undefined, we must begin to place equal emphasis on the means or process they use in reaching this diagnosis.*
> (Helfer, Slater and Goltz, 1971, p.48)

Recently, other researchers have stated that investigating how medical students reason clinically remains a priority and that future research should investigate relationships between different entities that might influence student learning (Dolmans and Wolfhagen, 2004; Epstein and Hundert, 2002).

### 2.4.1 Section Summary

Studies have demonstrated that reasoning processes of novices' differ from those of experts, but to date very few studies have been completed on how clinical reasoning develops (Groves et al., 2003a). As reported by Groves et al. (2003a), researching the clinical reasoning process may in turn aid the development of clinical reasoning in medical students. Further research into clinical reasoning in medicine is important for finding practical methods of improving the level of reasoning (Elstein and Schwartz, 2000). Comparing snapshots of experts' and novices' reasoning has yielded information about how their reasoning processes differ, but it has not given us any information about how a person's clinical reasoning may change over time. It appears that no longitudinal study of clinical reasoning has been attempted. Therefore, the study reported in this thesis was longitudinal in nature and investigated the development of particular medical students' clinical reasoning during their first two years of medical school.

## 2.5 FACTORS AFFECTING THE DEVELOPMENT OF CLINICAL REASONING

There is limited information about the process of clinical reasoning and although it is considered that clinical reasoning does not develop in isolation, researchers agree that there is little evidence on which to base this conclusion (Dolmans and Wolfhagen, 2004; Hamm, 1988). Although there may be a number of factors that impact on the ability of a student to reason clinically, time and funding constraints limited the scope of this study and it was decided to focus on the investigation of how critical thinking ability, knowledge base and approaches to learning affect the development of clinical reasoning. The ability to think critically is widely regarded as an important attribute for a tertiary student to display (Phillips and Bond, 2004). However, there is little reported data on why this is the case and how critical thinking ability affects medical student performance. Therefore, this study explored the effect of critical thinking ability upon clinical reasoning development. The impact of knowledge on clinical reasoning development was investigated in this study partly because it has been reported that clinical problem solving relies on knowledge (see section 2.2.3) and clinical problem solving is the end point of clinical reasoning (see section 1.1). It is likely that a factor affecting the end point of a process may also affect the process itself, so investigating how knowledge impacts on the development of clinical reasoning was deemed worthwhile. Students' approaches to learning have been reported to impact on some measures of tertiary student academic performance (see section 2.5.2). As valid and reliable instruments to measure approaches to learning are readily available (see section 2.6.3), as part of this study it was thought to be important to investigate how approaches to learning impact on clinical reasoning development, an integral part of clinical competence or medical student proficiency.

### 2.5.1 Critical Thinking Ability

There is little research that links critical thinking ability to the development of clinical reasoning, although there is some degree of overlap between these two entities. However, provided that the difference between clinical reasoning and critical thinking is not purely semantic, it seems likely that one's critical thinking ability may impact upon one's clinical reasoning ability. In order to validate this hypothesis, it is necessary to define critical thinking and compare it with clinical reasoning.

#### *2.5.1.1 The Definition of Critical Thinking*

The concept of critical thinking has been extensively explored in the past and many definitions of it have been discussed in the literature (Boreham, 1994; Brookfield, 1987; Ennis, 1993; Gellin, 2003; Halpern, 1998; Miller, 1992; Norman, 2002; Norris, 1985; Norris and Ennis, 1989; Paul, 1985; Scott and Markert, 1994; Siegel, 1988; Watson and Glaser, 1994).

Watson and Glaser defined critical thinking as

> 1. *Attitudes of inquiry that involve an ability to recognize the existence of problems and an acceptance of the general need for evidence in support of what is known to be true.*
> 2. *Knowledge of the nature of valid inferences, abstractions, and generalizations in which the weight or accuracy of different kinds of evidence are logically determined.*
> 3. *Skills in employing and applying the above attitudes and knowledge.*
>
> (Watson and Glaser, 1994, p.9)

Halpern (1996) defines critical thinking as the process of evaluating the result of one's thinking (the quality of a decision or how well a problem is solved) and states that the goals of critical thinking are to (1) recognise propaganda, (2) analyse hidden assumptions in arguments, (3) recognise deliberate deception, (4) assess credibility of information, and (5) work through problems/decisions in the best way. Halpern's (1996) definition encompasses Norris and Ennis' (1989) view that critical thinkers need to seek reasons, to try to be well informed, to use credible sources and mention them, to look for alternatives, to consider seriously viewpoints other than their own, to withhold judgment when the evidence and reasons are insufficient, and to seek as much precision as the subject permits. Halpern's (1996) view was also reiterated to a degree by Scott, Markert and Dunn

(1998, p.14) who defined critical thinking as "the ability to solve problems by assessing the evidence using valid inferences, abstractions, and generalizations".

The American Philosophical Association Delphi Research Report details a definition of critical thinking reached by the consensus of 46 international critical thinking experts in 1990.

> *Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological or contextual considerations upon which that judgment is based.*
> (Facione, 1990, p. 2)

These experts went on further to describe critical thinking in terms of the six cognitive skills and the sub-skills involved in this ability (Table 1). This consensus statement incorporates the definitions of critical thinking of Watson and Glaser, as well as others (Facione, 1990).

Table 1: Critical Thinking Skills According to the American Philosophical Association Delphi Research Report (Facione, 1990).

| **Cognitive Skills** | **Cognitive Sub-Skills** |
|---|---|
| Interpretation | categorization<br>decoding significance<br>clarifying meaning |
| Analysis | examining ideas<br>identifying arguments<br>analyzing arguments |
| Evaluation | assessing claims<br>assessing arguments |
| Inference | querying evidence<br>conjecturing alternatives<br>drawing conclusions |
| Explanation | stating results<br>justifying procedures<br>presenting arguments |
| Self-regulation | self-examination<br>self-correction |

The American Philosophical Association Delphi Report consensus statement acknowledges that there are many components incorporated into a definition of critical thinking (Facione, 1990). In addition to a number of required cognitive skills, it also requires an affective disposition (Facione, 1990). Thus a study of critical thinking should seek to define not only the skills involved, but should also attempt to study the disposition necessary for critical thinking.

#### *2.5.1.2 The Critical Thinking Disposition*

Having a critical disposition or spirit is held to be as important as having critical thinking skills, as critical thinking skills are of no benefit unless the person is disposed to use them when appropriate (Facione, 1990; Norris 1985 and 1989; Sternberg, 1983). Three requirements of a critical disposition based on work by Paul (1982) and Milgram (1963) are summarised by Norris (1985) as (1) reasoning about situations encountered in the world, (2) thinking critically about one's own thinking and (3) being of a disposition to act in accordance with one's thinking.

The American Philosophical Association Delphi Research Report (1990) also summarized the consensus view about the disposition of an ideal critical thinker. A critical thinker

> *is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focussed in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit.*
> (Facione, 1990, p. 2)

Almost two thirds of the 46 critical thinking experts who met to develop this Delphi Report (1990) were of the opinion that having critical thinking skills but not using them regularly means that one should not be considered a critical thinker (Facione, 1990). Thus it is understood that critical thinking is a concept that incorporates skills and a disposition to use them.

McPeck (1981) argued that thinking involves thinking about an entity, and the entity has to always be a particular entity, not just everything in general. Ballard and Clanchy (1995) also conceded that critical thinking skills have been shown to have domain specificity. Reasoning clinically involves self regulating one's interpretation, analysis, and evaluation of clinical information, creating arguments for hypotheses, making inferences from new information and explaining the reasoning behind the chosen diagnostic hypothesis. So critical thinking skills can be used to reason through a clinical case. However, critical thinking skills are not restricted to clinical cases. Medical students may have the ability to use critical thinking skills in another area, but be unable to transfer them to reasoning through a clinical case. Pithers (2000) reported that research into critical thinking in the context of tertiary student learning is an important area for further research. This highlights the potential value of the study reported in this thesis, which explored how commencing medical students' critical thinking ability impacted upon their ability to reason clinically.

### 2.5.2 Approaches to Learning

Another factor that may influence the development of a student's clinical reasoning is their approach to learning. The concept of an approach to learning was explained by Pask and Marton and Saljo in the 1970s (Marton and Saljo, 1976a and 1976b; Pask, 1976). Pask (1976) categorised people as comprehension, operational or versatile learners. Marton and Saljo (1976a and 1976b) distinguished two approaches to learning: deep and surface. Many other researchers have built upon this work. Biggs (1988) questioned whether 3 approaches to learning (deep, surface and achieving) actually existed. However, further analysis of Biggs' Study Process Questionnaire and approaches to learning made researchers conclude that indeed there are only two distinguishable approaches to learning, namely deep and surface (Biggs, Kember and Leung, 2001). A deep approach to learning is characterised by an interest in the subject matter of the task and the strategy is to maximise understanding and engage in the task properly (Biggs, 1993). A surface approach is based on an intention that is extrinsic to the real purpose of the task and involves investing minimal time and effort on the task whilst appearing to meet its requirements (Biggs, 1993).

There has been extensive discussion about approaches to learning in the medical field and some research has been done to investigate how approaches to learning may correlate with other entities. A deep approach to learning has been shown to correlate with understanding, reflection and critical reflection (Leung and Kember, 2003). There are no consistent findings about approaches to learning being related to gender (Duff, 2003), but using the Approach to Studying Inventory (ASI) or the Revised Approaches to Studying Inventory (RASI), increasing age has consistently been shown to correlate with a deep approach to learning (Richardson, 1995; Richardson, Morgan and Woodley, 1999; Sadler-Smith and Tsang, 1998). A deep approach to learning has also been associated with achievement in undergraduate education (Diseth, 2002; Diseth and Martinsen, 2003; Duff, 2003; Entwistle, Tait and McCune, 2000; Mattick, Dennis and Bligh, 2004; Newstead, 1992; Sadler-Smith, 1997).

Biggs, Kember and Leung (2001) have shown that an approach to learning can change as the approach is impacted by characteristics of the individual but also the teaching environment in which the individual learns. There is some evidence that medical students in traditional curricula tend to adopt a surface approach to learning whilst students in a problem-based learning (PBL) curriculum are more likely to adopt a deep approach to learning (Newble and Clarke, 1986; Newble and Entwistle, 1986; Vu, van der Vleuten and Lacombe, 1998). Researchers have also identified that students' learning has become more surface in the first year of tertiary education, perhaps due to curriculum overload (Biggs, 1987; Johnston, 2001; Kember and Gow, 1990; Richardson, 2000). However, both traditional curricula and PBL curricula differ substantially between medical schools, and rarely has research been done across multiple institutions to verify this assertion. Nevertheless, it has been argued that deep learning may occur when students integrate new knowledge into their pre-existing understanding of concepts (something that is encouraged when learning is done in the context of clinical cases through PBL in an integrated curriculum), and so this had led to claims that a PBL curriculum fosters a deep approach to learning (West, Pomeroy, Park, Gerstenberger and Sandoval, 2000). As a deep approach to learning also may help students to develop conceptual frameworks or elaborated knowledge which is useful for developing expertise in critical thinking and clinical problem solving, perhaps a deep approach to learning impacts positively on the development of a student's clinical reasoning (West et al, 2000; Woods, Brooks and Norman, 2005). However, to date no research has detailed how a deep approach to learning, a PBL-based integrated curriculum and the development of clinical reasoning may be related.

Sternberg (1997) has reported that an individual's approach to learning can be modified. An approach to learning is affected by the teaching environment in which a student learns (Ramsden and Entwistle, 1981). If a deep approach to learning is deemed to impact positively on the development of clinical reasoning, investigating students' approaches to learning at Medical School may provide an impetus to create an environment that fosters a deep approach to learning, if it does not exist already. This may then promote more effective learning of clinical reasoning, resulting in more expert clinical reasoners and ultimately more clinically competent doctors. Therefore, this study sought to investigate how students' approaches to learning impacted on their clinical reasoning development.

## 2.6 THE MEASUREMENT OF FACTORS TO BE STUDIED

While acknowledging that there may be many factors that influence the ability of a student to reason clinically, this study focused on 1) critical thinking ability, 2) knowledge base and 3) approaches to learning. Studying clinical reasoning and the factors that influence its development required the capacity to measure each of these entities. This section describes methods of measuring clinical reasoning, critical thinking ability and approach to learning. The method used to measure knowledge databases in this study is described in Chapter Three.

### 2.6.1 Clinical Reasoning Ability

As the ability to solve clinical problems has been seen as important measure of clinical competence, assessing the clinical problem solving ability of medical students has been the focus of many reported studies and numerous instruments exist to measure this entity. Rimoldi's Test of Diagnostic Skills involved subjects being presented with clinical information about a patient and their chief complaint and scoring the number of questions the subjects needed to ask in order to make a diagnosis (Rimoldi, 1961). Programmed Tests (used by the National Board of Medical Examiners in the United States of America) involved subjects reading through a test booklet of clinical information about a patient, making decisions about a diagnosis, and then selecting investigations they would perform to confirm this diagnosis (Hubbard, Levit, Schumacher and Schnabel, 1965). The results of the investigations were then given and the subjects presented with further management decisions before being scored for the number of correct decisions they made. This score was purported to be a measure of a student's clinical judgement (Hubbard et al., 1965). In a further development, Case Study Problems were used to evaluate cognitive levels above factual recall, in addition to sensory discrimination (Fleisher, 1972). Bordage (1990) developed the Diagnostic Thinking Inventory (DTI) to measure degrees of flexibility in thinking and degrees of knowledge structure in memory (Bordage, 1990). However, the primary focus of all of these instruments was to analyse clinical problem solving ability and not specifically study clinical reasoning.

Instruments measuring the process of problem solving or diagnosis and not just its outcome have included Branched Management Problems, Diagnostic Management Problems and Sequential Management Problems (Berner, Hamilton and Best, 1974; Helfer and Slater 1971; McGuire and Babbott, 1967; Williamson, 1965). These instruments were all forerunners of Patient Management Problems (PMPs). PMPs involve presenting a subject with some patient information. The subject then collects further history and examination data in a branching or sequential manner (different methods of concealing the data until it is requested are employed). Finally, the subject may be asked to request investigations and make management decisions after giving a diagnosis (Newble, Norman and van der Vleuten, 2000). Subjects' PMP scores for proficiency, thoroughness and efficiency are determined by comparing their method of working through the PMP with an expert or criterion group's method (Newble et al., 2000). PMPs have been reported to have low test reliability, difficulties in scoring and there are low correlations across different PMPs (performance on one PMP is a poor predictor of performance on another PMP), so it has been concluded that PMPs have psychometric problems and are not a valid measure of clinical reasoning (Goran, Williamson and Gonella, 1973; McCarthy, 1966; Newble, Hoare and Baxter, 1982; Norman and Feightner, 1981).

More recent research has focussed on students' clinical decision-making skills by asking them to identify key features, which are those features necessary for the identification and management of the clinical problem (Bordage, Brailovsky, Carretier and Page, 1995; Page, Bordage and Allen, 1995). Bordage et al. (1995) published strong evidence for the content validity of 59 key features identified in problems that are now used in the Canadian National Examination of Clinical Decision-making Skills. Maastricht University in The Netherlands also used the key features approach to measure clinical problem solving (van der Vleuten and Newble, 1995). However, the key feature problems are short and only focus on the few important parts of problem solving. Ultimately they test clinical problem solving and not clinical reasoning (Page et al., 1995).

Clinical Reasoning Exercises (CREs), which involve an oral or written examination of questions about multiple clinical cases, have been used to test clinical reasoning. An initial evaluation of the CREs suggested that they had an acceptable inter-rater reliability, inter-case correlations in the accepted range and evidence of concurrent validity, but questionable test reliability (Neville, Cunnington and Norman, 1996). However, other researchers have disagreed and stated that CREs test student awareness of the underlying mechanism of disease and not clinical reasoning (Wood, Cunnington and Norman, 2000). It has been reported that Maastricht University in the Netherlands has used the Clinical Reasoning Test (CRT) to examine clinical reasoning (Schmidt, Machiels-Bonagaerts, Hermans, ten Cate, Venekamp and Boshuizen, 1996; Boshuizen, van der Vletuen, Schimdt and Machiels-Bonagaerts, 1997). The CRT comprises 30 short clinical cases for which subjects are asked to give a differential diagnosis. The test was developed to measure knowledge and clinical reasoning skills in a problem based learning curriculum. However, after studies using this instrument, researchers have concluded that the CRT only measures a person's knowledge and the ability to make a differential diagnosis and not the ability to reason clinically (Boshuizen, Machiel-Bongaerts, Schmidt and Hermans, 1995; Boshuizen at al., 1997).

Newer tests of clinical reasoning proposed by Beullens, Struyf and Van Damme (2005) are extended matching questions (EMQs). EMQs are multiple choice questions that involve a clinical case stem and then subjects are asked to select the most likely diagnosis out of eight or more listed options. When solving the clinical problems in the test, participants were instructed to verbally describe their thought processes (Beullens et al., 2005). Scores for the EMQs were a composite of the number of correct diagnoses and what type of reasoning two independent scorers heard the subjects use (forward, backward, generating, limitating or eliminating) (Beullens et al., 2005). However, the questions in this test are based on the assumption that the best indicator of clinical reasoning is the diagnosis and therefore only questions concerning pathogenesis or diagnosis were included. Thus the EMQs are described as a way of measuring diagnostic reasoning or clinical problem solving and not clinical reasoning in the way it is defined in this present study (see section 1.1).

Clinical Reasoning Problems (CRPs) are the only instruments reported to actually measure the process of clinical reasoning (Groves, Scott and Alexander, 2002). CRPs consist of a patient's history and physical examination findings. Subjects nominate two preferred diagnoses for the CRP, listing the clinical findings they considered in reaching these diagnoses. Subjects are also asked to indicate whether the clinical findings support or detract from their nominated diagnoses. A subject's score for the CRP is comprised of marks given for indicating critical clinical findings and whether these findings support or oppose the nominated diagnoses. In a study of the CRP performances of 92 self-selected volunteer medical students (out of a possible 220 enrolled students), Groves et al. (2002) concluded that CRPs were a reliable way of measuring clinical reasoning. However, more data is needed to verify the construct validity of CRPs (Groves et al., 2002).

In summary, instruments to measure clinical problem solving ability exist and have been designed on the premise that solving a clinical problem correctly is the result of using sound clinical reasoning (Groves et al., 2002; Newble et al., 2000). However, it is now evident that clinical problem solving is an end product of clinical reasoning and although these two entities overlap, they have distinct qualities. Researchers have been encouraged to develop new instruments to measure clinical reasoning (Newble et al., 2000). To date there is still no valid, reliable method of measuring the process of clinical reasoning, so this present study involved the development of such an instrument.

### 2.6.2 Critical Thinking Ability

There are many instruments available to measure critical thinking. The Watson-Glaser Critical Thinking Appraisal (WGCTA) is acknowledged to be one of the best available instruments for measuring the ability to think critically (Berger, 1985; Helmstader, 1985; Woehlke, 1985). The WGCTA is therefore the most frequently used test of critical thinking for research and evaluation purposes (Geisinger, 1998; Norris, 1985; Woehlke, 1985). However, the validity of the WGCTA has been questioned as it determines critical thinking ability only through reading. In addition, the test’s scope and content has been reported as narrow and most of the studies of validity through content and construct analysis were done on older versions than the present WGCTA (Woehlke, 1985). Raw scores from subtests on the WGCTA on an individual basis cannot be used, as there is little reliability (Berger, 1985). As the WGCTA is now managed as a commercial product, it is also extremely expensive to use on large cohorts of subjects.

Instruments other than the WGCTA do exist to test critical thinking skills and dispositions: the California Critical Thinking Skills Test (CCTST), the California Critical Thinking Disposition Inventory (CCTDI), the Cornell Critical Thinking Test (CCTT), the Ennis Weir Critical Thinking Essay Test (EWCTET), the Wagner Appraisal Test (WAT) and the Critical Reasoning Test Battery 2 (CRTB2). However, reliability and validity issues have been identified for each of these instruments. The CCTST does not have appropriate psychometric properties to assess individual abilities or sufficiently stable reliability, and its analysis subscale has been shown to have exceptional weakness in all administrations (Bondy, 2001; Michael, 1995). The CCTDI also has psychometric weaknesses as the validity and the reliability of its individual subtests are questionable (Callahan, 1995; Ochoa, 1995). It has been reported that the CCTT does not have adequate validity and further exploration into the reliability and validity of the test is warranted (Hughes, 1992; Malcolm, 1992). There is a lack of reliability data for the EWCTET and its construct, predictive and concurrent validity have not been studied (Poteet, 1989; Tompkins, 1989). The WAT is a new test based loosely upon the WGCTA (Wagner and Harvey, 2003). Currently, there is little evidence of the strength of its psychometric properties. There is also a lack of objective evidence for the reliability and validity of the CRTB2, and it is expensive to use on large cohorts of subjects.

Although there are a number of critical thinking tests, the limitations of each instrument have restricted their potential use in this study. Due to the limitations of the critical thinking tests available, researchers have advocated designing a test to suit the context being studied (Ennis, 1993; Facione, 1990). Therefore, this study explored methods for judging students' critical thinking ability as it applies to the context of clinical reasoning.

### 2.6.3 Approaches to Learning

In contrast to the limited number of valid, reliable instruments available to measure the process of clinical reasoning and critical thinking, many instruments exist to measure student learning. This section describes the range of tests available and the rationale for using Biggs et al.'s (2001) Revised Two Factor Study Process Questionnaire (R-SPQ-2F) to measure the approaches to learning of the first and second year medical students at The University of Adelaide, South Australia.

Two major theories are the source of current learning process and learning environment questionnaires (Entwistle and Waterson, 1988). Information Processing (IP), which originates from cognitive psychology, stems from the idea that there are levels of processing in memory. Research with a 62-item Inventory of Learning Processes revealed four factors of learning (deep processing, elaborative processing, fact retention and methodical study) that applied to subjects (Schmeck, Ribich and Ramanaiah, 1977; Fox, McManus and Winder, 2001). However, the IP theory does not take into account the effect a learning environment may have on study processes. Qualitative research involving students' reports of their own study habits when reading an academic article yielded results that supported an alternative theory described as the Student Approach to Learning (SAL) (Marton and Saljo, 1976). The SAL theory is that students' approaches to learning can be either deep (they intend to understand the meaning of the author) or surface (they intend to memorise facts and details), and that the approach a student adopts is affected by the context in which the learning occurs (Fox et al., 2001).

Learning styles in isolation have been measured by the Revised Inventory of Learning Processes (ILP-R). The ILP-R is a 160-item questionnaire in the form of statements about study behaviours, attitudes, opinions and motivations. Subjects rank along a Likert scale how strongly they agree with the statements in the ILP-R, and information about the subject's personality and learning style is generated (Schmeck and Geisler-Brenstein, 1991). Quantitative measurements of approaches to learning according to the SAL theory are made by instruments such as the Study Process Questionnaire (SPQ), the Approaches to Studying Inventory (ASI), and the Revised Approaches to Studying Inventory (RASI) (Biggs, 1987; Entwistle and Ramsden, 1983; Entwistle and Tait, 1994). Each of these instruments involves subjects reading statements about learning behaviours and ranking on a Likert scale how strongly the statement describes their own behaviour. Information is then generated from the ASI and RASI about which of four approaches to, and motivations for, learning best describe subjects' behaviour (achieving, meaning, reproducing or non-academic). Students' responses to the SPQ were used to determine whether they adopted a deep or surface approach to learning.

Use of the ASI to measure approaches to learning is limited. The subscales of ASI have low reliability. Although it may be a potentially useful measure of students learning styles in the short form, further refinements are required of the ASI before it can be used generally (Kember, Wong and Leung, 1999; Newstead, 1992; Richardson, 1994). In contrast to the ASI, the SPQ has been used extensively, validated and found to be reliable (Fox et al., 2001; Murray-Harvey, 1994; Newble, Entwistle, Hejka, Jolly and Watson, 1988; O'Neil and Child, 1984; Watkins and Hattie, 1981; Zhang, 2000; Zhang and Sternberg, 2000). However, the SPQ was revised in light of research indicating that there are actually only two dimensions of the approaches to learning (Kember and Leung, 1998; Kember, et al., 1999; Wong, Lin and Watkins, 1996; Meyer and Parsons, 1989). A revised two-factor instrument used to measure approaches to learning, the R-SPQ-2F, was therefore developed (Biggs et al., 2001).

Using the R-SPQ-2F to measure approaches to learning means that relationships between this entity and other constructs, such as clinical reasoning, can be explored. As approach to learning is influenced by the teaching context, the R-SPQ-2F can also be used to explore the relationship of this environment to students' approaches to learning by measuring differences between students' responses obtained before and after they engage with the teaching context (Biggs et al., 2001; Kember et al., 1999). For these reasons, the R-SPQ-2F was the instrument used to measure the approach to learning of the students in this study.

## 2.7 CHAPTER SUMMARY

Past research has focussed on the progression from a novice to an expert clinical problem solver, the importance of biomedical knowledge in clinical problem solving, and the different methods involved in clinical reasoning. This review has identified that limited research has been completed on the development of clinical reasoning ability, especially in undergraduate medical students. Few instruments are available to measure the process of clinical reasoning. In addition, it was identified that apart from knowledge, other factors that may affect the development of clinical reasoning have not been considered. The skills involved in clinical reasoning seem to overlap with those involved in critical thinking but there is little research on this relationship. This review also identified that limited evidence is available as to whether approaches to learning impact upon the development of clinical reasoning. Therefore, the aim of the present study was further investigate the concept of clinical reasoning by exploring the development of students' clinical reasoning ability, and to assess how and to what extent critical thinking ability, knowledge base and approaches to learning impact upon this process. The following research questions were the focus of the study:

1. How can student clinical reasoning be measured?
2. How do students' clinical reasoning abilities change as they progress through the program?
3. What factors influence the development of student clinical reasoning ability?
4. How can students' critical thinking ability be measured?
5. How do students' critical thinking abilities influence their clinical reasoning?
6. How do students' knowledge bases influence their clinical reasoning?

7. How do students’ approaches to learning influence their clinical reasoning?

# CHAPTER THREE - THE RESEARCH DESIGN

## 3.1 INTRODUCTION TO THE RESEARCH DESIGN

The methods of a study should be determined by the research questions (Newman, Ridenour, Newman and Demarco, 2003; Brannen, 2004). Clinical reasoning development seems to be a complex process, and one that is difficult to measure. In order to explore the development of clinical reasoning and factors that might impact upon this, it was deemed necessary to use a research design that incorporated qualitative and quantitative methods. Qualitative and quantitative research approaches are complementary parts of an investigation (Denzin and Lincoln, 2005; Howe and Eisenhart, 1990; Patton, 2002; Salomon, 1991). As educational research can be complex, and the relationships between entities multifaceted, a holistic approach using both qualitative and quantitative methods of research is warranted (Dauphinee and Wood-Dauphinee, 2004; Entwistle and Ramsden, 1983; Metz, 2000). The research design of this study enabled insights to be gained about the development of clinical reasoning from qualitative case studies conducted with a subset of students, and also from results collected from quantitative research conducted with a large cohort of medical students. An introduction to these two types of research as applied in this study will be described in the next section.

## 3.2 QUANTITATIVE AND QUALITATIVE RESEARCH

Quantitative research deals with numbers and proportions (Newman et al., 2003). It documents changes and therefore can identify the issue at hand (Irby, 1990). Quantitative research is based on scientific or quasi-experimental designs and uses instruments to collect data. The purpose is to establish objective and direct causal links or associations between specific circumstances and outcomes. The merit of quantitative research is readily accepted by the academic community, particularly because the validity and reliability of the research is relatively simple to ascertain using statistical tests (Brannen, 2004). The validity of a scale is the extent to which it measures what it intended to measure, and the reliability of a scale is a measure of how free it is from random error (Pallant, 2001). The validity and reliability of the quantitative tools used in this study are described in Chapters Four and Five.

Qualitative research deals with meanings or characteristics (Newman et al., 2003). It offers insight into the meaning of behaviours and can help to clarify the issue being investigated (Bryman and Burgess, 1994; Sandelowski, 1997). One important feature of this form of research is the role of the researcher as the human instrument for data collection. The researcher can respond to all cases in a situation, be adaptable (collect information for multiple factors simultaneously), capture a more holistic view of the situation, immediately process information and generate hypotheses, obtain clarification or amplification from participants and explore atypical or idiosyncratic responses. All of these elements help to establish the meaning of the findings. The qualitative components of this study are considered here and in Chapter Six.

### 3.2.1 Sampling Strategies

There are many sampling strategies involved in qualitative research (Patton, 2002). As quantitative research is usually concerned with confidently generalising findings about a sample to a larger population, sampling has to be random and statistically representative in order to achieve this outcome. However, sampling strategies in qualitative research are utilized in order to gain a deep understanding from information-rich cases rather than enable empirical generalisations (Patton, 2002). Cases are selected purposefully as being those that will provide the most information about the phenomenon under scrutiny (Merriam, 1988). There are many strategies of purposeful sampling and the strategy chosen will depend upon the research question being asked. Purposeful random sampling of students in this program was employed using predefined criteria (see section 6.1) so that students with differing critical thinking abilities and approaches to learning were selected to participate in interviews. This sampling strategy was selected in order to highlight any insights about factors affecting clinical reasoning development and how this may vary between students with different abilities. Further into the study, other students with differing levels of clinical reasoning ability were purposefully selected for interviews and then for case studies.

### 3.2.2 Sample Sizes

In quantitative research, the sample size is selected on the basis of the number of subjects needed for the findings to be confidently generalisable to the larger population from which it was drawn (Patton, 2002). The quantitative research in this study involved whole student year groups (*N* >130) for this reason. However, qualitative research is conducted in order to maximize the potential for extrapolations, not generalisations, and therefore there are no specific rules about sample size for these studies. Extrapolations are case-derived ideas about the possible applicability of findings to other circumstances which are similar, but not identical to the one studied (Patton, 2002). Whereas generalisations reached through quantitative analysis tend to be conclusions, extrapolations from qualitative research are findings that need further testing. The goal of purposeful random sampling is credibility and not representativeness. The sample size will be too small for statistical generalisations, but is selected in order to maximize the potential for extrapolations. Lincoln and Guba (1985) recommend that redundancy should be the primary factor that determines sample size in qualitative research (Lincoln and Guba, 1985). If striving to maximize the amount of information yielded from a study in order that extrapolations can be made, the sampling is stopped when no extra information is gained from freshly sampled units, i.e. when the information from new units becomes redundant (Lincoln and Guba, 1985). The sample size for this study was determined by this principle of redundancy (see section 6.1 for further information).

### 3.2.3 Case Study Research

Case studies represent one form of qualitative research. Other theoretical methods of qualitative inquiry include Ethnography, Phenomenology, Heuristic Inquiry, Hermeneutics and Grounded Theory, although individual researchers classify these qualitative methods of research in different ways (Creswell, 1998; Denzin and Lincoln, 2000; Patton, 2002; Wolcott, 1992). Case studies are a useful technique to apply when there is need for further explanation of factors that impact on a particular problem as it provides a way of simultaneously exploring numerous variables that may be of importance (Merriam, 1998). The literature about the factors that affect clinical reasoning was limited and this meant that a heuristic and inductive approach rather than a hypothesis-testing approach was appropriate for this study. Case studies are particularistic, descriptive, heuristic (exploratory) and inductive (they involve exploring relationships or concepts, rather than proving or disproving hypotheses) (Merriam, 1988). Insights gained through case studies can help to guide further research, and exploration of an educational process can affect and possibly even improve practice (Merriam, 1998). For these reasons, case studies were chosen for this research design.

Even though outweighed by their benefits, the limitations of case studies must be considered. Case studies involve many hours of assimilating data, are complex to report, are sensitive to the integrity of the investigator and there are ethical issues involved when the investigator is part of the study context. Establishing the reliability (consistency), internal validity (truth value) and external validity (transferability or applicability) of case study research findings can also be problematic (Merriam, 1988; Goetz and LeCompte, 1984). These issues are addressed in the next section and in Chapter Seven.

### 3.2.4 Research Validity, Reliability and Trustworthiness

Steps can be taken to maximize the validity, reliability and trustworthiness (consistency, truth value and transferability) of research. Trustworthy qualitative results are analogous to valid and reliable quantitative results (Miles and Huberman, 1984). The trustworthiness of a study is directly related to the credibility of the investigator and the rigor of the methods applied in the research (Denzin and Lincoln, 2005; Lincoln and Guba, 1986). This section explores the terms “validity”, “reliability”, “consistency”, “truth value” and “transferability” and introduces how consideration of these issues impacted upon this study.

#### *3.2.4.1 Validity*

The validity of an instrument is determined by whether it measures what it is purported to measure (Pallant, 2001). Face validity is a subjective opinion about whether the instrument appears to measure what it is purported to. The strength of the face validity of an instrument can be augmented by having it validated by people with expert knowledge of instrument construction and the concept being measured. The content validity of an instrument pertains to whether the concept the instrument is purported to measure is actually examined by it. This involves defining and examining the concept to be measured and ensuring that each component is assessed by the instrument. The construct validity of an instrument pertains to whether subjects’ scores for a concept according to the instrument correlate with their scores according to an established, valid instrument known to measure the concept in question. When an instrument measures a trait that is thought to change with time, testing of the instrument's construct validity is enhanced if the subjects' are measured by both the instrument in question and the established, valid instrument during the same assessment period. This decreases the potential for differences in subjects' performance scores to be due to something other than differences in the instruments used to measure the performances. The validity of the quantitative instruments used in this study is outlined in Section 3.4.1 and in Chapters Four and Five.

#### *3.2.4.2 Reliability*

The reliability of a quantitative instrument is an estimation about the degree to which it produces consistent results under the same conditions (Pallant, 2001). Test-retest reliability is the extent to which a subject's score is the same as measured by the instrument on two different occasions. This can only be calculated meaningfully if the trait being measured is thought to have remained the same between tests. As such, test-retest reliability was not calculated for some of the instruments used in this study, as the underlying traits were hypothesised to have changed between measurements. However, other measures of reliability, namely internal consistency, inter-rater reliability and intra-rater reliability, were calculated for the instruments used in this study. Internal consistency is an estimation of the extent to which components of an instrument measure the same entity during a single administration of the instrument. This is calculated through correlations and reported as a Cronbach's Alpha number between zero and one. The closer Cronbach's Alpha is to one, the more reliable the instrument is estimated to be. Inter-rater reliability is the correlation between different raters' scores for the same subjects' performances at the same time using the same instrument. Intra-rater reliability is the correlation between one rater's scores for the same subjects' performances using the same instrument but calculating the scores on two separate occasions. The reliability of the quantitative instruments used in this study is reported in Sections 3.4.1 and 4.3 and in Chapter Five.

#### *3.2.4.3 Consistency*

Reliability in qualitative research is assessed by determining the consistency of results, i.e. whether others would agree that given the data obtained, the results are plausible (Merriam, 1988). In a qualitative context, the consistency of a study is enhanced by detailing the investigator's position and assumptions, the context in which the data was collected, the basis of selecting subjects, providing a description of the subjects, and by outlining an audit trail so that other researchers can replicate the study (Goetz and LeCompte, 1984). Details about the investigator are provided in this section, the context in which the data was collected is reported in section 3.3, and all the other factors are described in Chapter Six.

In this study, the researcher was a medical doctor who used clinical reasoning and interviewing skills in her practice of Emergency Medicine. The researcher was also a Problem-Based Learning (PBL) and Clinical Skills tutor at The University of Adelaide Medical School. Although the researcher did not tutor or have assessment responsibilities for the particular students involved in this study, having been a medical student and tutoring students in other years of Medicine at the same school gave the researcher insight into the general development of undergraduate medical students' clinical reasoning ability. The researcher had had a limited experience of PBL as a medical student, although this was within the bounds of a traditional curriculum dissimilar to the context within which this study was conducted. The researcher's views were influenced by medical education colleagues at The University of Adelaide.

The underlying assumptions and biases of the researcher included the belief that clinical reasoning was a multifaceted process that was difficult to describe succinctly and that clinical reasoning was an important part of doctors' clinical competence. Therefore, the researcher believed that the development of this set of skills was worth fostering at medical school. It was thought that the development of clinical reasoning was promoted better by an integrated, PBL-based curriculum, rather than a traditional one. Critical thinking skills and approaches to learning were considered to be entities that may impact on the development of clinical reasoning, and it was supposed that better critical thinkers and students with a deep approach to learning would develop superior clinical reasoning. It was thought that investigating the development of clinical reasoning would provide insight into to possible changes that could be made at an individual and curricular level to promote better development of clinical reasoning.

### *3.2.4.4 Truth Value*

It is well-documented that using multiple ways to collect data (triangulation of methods) about the same entity is a useful approach to research, as the disadvantages of one method are often the advantages of another, and therefore triangulation increases the truth value of the study findings (Drescher, Warren and Norton, 2004; Johnson and Turner, 2003; Mathison, 1988; Morse, 2003; Shea, Arnold and Mann, 2004). For this reason, triangulation of data collected by qualitative and quantitative methods was performed in this study. Triangulation of sources for the case studies (the case studies in this research involved analysing student examination papers, PBL journals, PBL tutor reports and standardized open-ended interviews with students) was also used in order to determine whether perspectives from multiple sources confirmed the emerging findings, thereby increasing the truth value of these findings.

Member checks and peer examination are reported as methods of improving the truth value of research (Merriam, 1988). Therefore, the case study information in this present investigation was reported back to the students from whom it was derived in order to check if they considered that the results were plausible. Professional colleagues commented on findings as they developed. The fact that case study data were gathered over a long period of time (two years) also increases its validity (Merriam, 1988). Finally, the researcher's biases have been detailed (see section, 3.2.4.1) to clarify any assumptions that may influence the study's truth value.

### *3.2.4.5 Transferability*

Extrapolations from qualitative research cannot be generalised to larger populations in the same way as may be possible for the results of quantitative research (see section 3.2.1). However, it is important to maximize the transferability or applicability of case study results, even if they are not generalisable. Applicability of the case studies has been enhanced by cross-case analysis (see Chapter Seven), as examination of related and dissimilar cases further illuminated single-case insights, focusing the results and adding to their validity (Miles and Huberman, 1994). Applicability has also been achieved in this study by providing rich and thick descriptions of the case studies (see Chapter Six) and detailing their typicality (see section 3.3 below for the context of the study), so that judgments can be made about findings from this study being transferable to other situations (Goetz and LeCompte, 1984).

## 3.3 THE CONTEXT OF THIS STUDY

The context in which the study took place needs to be described before the research design can be further explained. The development of first and second year medical students' clinical reasoning was studied at The University of Adelaide, South Australia. This section explains 1) the process by which clinical reasoning is modelled and practised in the Medical School and 2) how students' critical thinking ability, knowledge bases and approaches to learning, factors that may impact on the development of their clinical reasoning ability, are considered in the medical curriculum.

### 3.3.1 The Program

#### *3.3.1.1 Assessment*

It widely recognised that learning is driven by assessment (Biggs, 1979; Blumberg and Michael, 1986; Newble and Jaeger, 1983; Marton and Saljo, 1976a and 1976b, Sadler-Smith and Tsang, 1998). Clinical reasoning development is an important aim of the medical program, and it was understood that student learning would need to be integrated to facilitate the development of this set of skills. Therefore, in order to encourage integrated learning and clinical reasoning, students in the program are assessed by integrated examinations (a practical or Observed Structured Clinical Examination (OSCE), a modified-essay question paper, a short answer paper and a multiple choice paper) and part of the assessment involves questions that focus on testing clinical reasoning.

A student providing an accurate diagnosis is not necessarily good evidence that they have adequately understood the concepts or have an associated clinical reasoning ability. Therefore, as part of their modified-essay question paper, students in this program are given one question which specifically tests their clinical reasoning ability as developed through the PBL model. This question presents students with a patient's history, with or without physical examination findings. The student is required to review and recognize the significance of the data, detail up to four hypotheses that best explain the patient's illness, and then indicate with brief reasons the data that support and detract from each hypothesis.

The student then continues by explaining the mechanism for each hypothesis. Finally, the student details up to four of the most important areas where they consider their knowledge is insufficient in order for them to explain the patient's illness (four learning issues). Students have up to one hour to complete this examination question. The aim of this assessment which aligns with the PBL processs was to stimulate students to adopt a deep approach to learning, regardless of what approach to learning they may have used prior to medical school.

#### *3.3.1.2 The Curriculum*

The medical program also promotes the development of clinical reasoning by having a horizontally and vertically integrated curriculum that is delivered in a student-directed, problem-based learning manner. Horizontal integration involves clinical cases in problem-based learning sessions being used as the focus for learning in the streams of 1) Scientific Basis of Medicine, 2) Clinical Practice and 3) Medical Personal and Professional Development. Students are encouraged to use the information they learn in reasoning clinically across the curriculum. Vertical integration of the curriculum involves concepts in each of the three streams being introduced and reintroduced in subsequent years with increasing complexity, starting with a greater focus on basic science in first year, and building to clinical management skills by third year and beyond. This allows students to develop an elaborated knowledge base and the skills of clinical reasoning over time, by ensuring that students learn information in context at each level that they can use for practising their clinical reasoning.

In years one to three, clinical reasoning ability is developed through the PBL process. Groups of 8-10 students meet for two-hour blocks three times a week to work on a clinical paper case. Each case takes four sessions. The model of problem based learning emphasizes the learning associated with the case and does not focus on problem solving. In this form of PBL, initial history details of the patient are presented in session one. Further history details, the physical examination findings, investigation findings and results of management are gradually released to medical students as they ask for the information over sessions two to four. This enables students to practise the skill of inquiry, which is an important part of clinical reasoning (Barrows, 1990). For each question, students must justify why they need the information, predict what the results will be on the basis of their hypotheses and explain how both positive and negative results will impact upon their reasoning about the likelihood of their hypotheses explaining the patient’s condition. The usefulness of this method of PBL for learning clinical reasoning is supported by researchers’ conclusions that people who work through a problem before being given the solution have increased analogic transfer (Schmidt, Norman and Boshuizen, 1990).

During the PBL sessions, students are encouraged to analyse information in the clinical case, identify the relative significance of the details given, and hypothesise mechanisms for the symptoms, signs and investigation results detailed by applying relevant prior knowledge to this particular case. Students are encouraged to discuss ideas in a logical manner and support individual steps in the reasoning process with relevant findings and specific information from the case. This is in line with research that has demonstrated that increased analogic transfer also occurs if people test hypotheses (Lewis and Anderson, 1985), teach the problems to another person (Brown and Kane, 1988), or form an explanation of the problem (Ahn, Brewer and Mooney, 1992).

Another important part of clinical reasoning is evaluation or ascertaining the plausibility of one’s hypotheses when provided with new data. In order to progress through the PBL case, students ask questions to clarify details within the case, identify areas where further knowledge is required, and then do private study outside tutorials. When the students re-group, further testing of hypotheses is done in light of new information or discussion. Students from within the group have the opportunity to summarise their reasoning and evidence for the working hypothesis and distinguish it from competing/alternative hypotheses at least once a case.

In summary, the PBL approach used in the early years of this program encourages the use of hypothetico-deductive reasoning. The curriculum was designed this way as hypothetico-deductive reasoning aids intelligent history taking and physical examination, as well as emphasising the need to form elaborated knowledge structures of basic scientific understanding and mechanisms. The use of other more expert-type clinical problem solving skills (for example pattern matching or working with schemes) by students is discouraged until they have sufficient knowledge databases to utilise these skills intelligently.

Databases that a student builds for clinical reasoning and problem solving need to contain basic science knowledge but must also include other types of knowledge, for example knowing the likelihood or probability of diseases in groups of people, understanding the presentation of diseases and their natural history and understanding the relative weightings of key features in a case. For clinical reasoning, students need to learn, elaborate and link these different databases in a way that will then foster easy retrieval and application of this knowledge in new situations. PBL encourages this process as students develop their understanding of the relevant concepts as they integrate and apply the information when analysing their case scenarios.

In addition to PBL cases, the program enables students to develop their clinical reasoning through their clinical skills teaching sessions. Starting in first year, students have clinical skills sessions once a week. These sessions allow students to practise their clinical reasoning by eliciting patient symptoms and signs, talking through the scientific and clinical elements of the case with their tutors and reasoning through likely diagnostic hypotheses for the presentation.

Thus through both integrated assessment practices and an integrated curriculum design of PBL sessions, clinical skills practice, support lectures, small group work and resource time in the anatomy and pathology laboratories, the medical program aims to promote the development of students' clinical reasoning ability.

### 3.3.2 The Role of Critical Thinking

Ideally all students should develop critical thinking skills and dispositions (Jones, McArdle and O'Neill, 1995). The University of Adelaide states that one of its ideal graduate attributes is the ability to think critically (Boumelha, 2003). It has been reported from students that their critical thinking increased after PBL was introduced (Birgegard, 1998). In-depth processing (i.e. characteristic of critical thinking or deep inquiry) is needed in order to practise deductive reasoning (i.e. working out clinical inferences from available data), to recognize unstated assumptions by weighing evidence, and to distinguish between weak and strong arguments (Kamin, O'Sullivan, Deterding and Younger, 2003). Critical thinking was defined in Chapter Two and includes self-directed learning, creative thinking and problem solving and therefore reflects many of the PBL goals (Kamin et al., 2001). Ultimately, using PBL may help students to develop this higher order critical thinking skill.

Throughout the first three years of the medical program, students are involved in PBL. However, there is no evidence as to the extent that critical thinking impacts on clinical reasoning ability. Therefore, this study explored the development of student critical thinking ability during their PBL program to ascertain to what extent there was an association or a relationship between this and the development of their clinical reasoning ability.

### 3.3.3 The Role of Approaches to Learning

Approaches to learning have been widely investigated and much of the literature on medical learning is summarized by Harvey (2003) who stated that "to be an effective, independent and self-directed lifelong learner is critical for undergraduate medical programs" (Harvey, 2003, p. 1259). It has been concluded that PBL helps to make students better self-directed learners (Blumberg and Michael, 1992; Dolmans and Schmidt, 1996; Hill, Rolfe, Pearson and Heathcote, 1998; Kaufman and Mann, 1996; Ryan, 1993; van den Hurk, Wolfhagen, Dolmans and van der Vleuten, 1999), and so it has been assumed that the Adelaide PBL medical students are self-directed learners.

It has also been reported that PBL causes students to adopt a deep approach to learning rather than a surface approach (Coles, 1985; de Volder and de Grave, 1989; Iputo, 1999; Newble and Clarke 1986; Schmidt, Dauphinee and Patel, 1987). Assessment that involves reproducing facts rather than demonstrating an understanding of the interaction between facts and concepts encourages students to have surface rather than deep approaches to their learning (Morris, 2001; Tang 1998). The PBL program that was part of this present study aims to stimulate students to adopt a deep approach to learning, regardless of what approach to learning they may have used prior to medical school. Further research is necessary to assess what approach to learning is adopted by medical students successful at clinical reasoning and longtitudinal studies of students may help to identify how these learning styles can change (Knox, 1984; Robotham, 1999). Therefore, the extent to which a student's approach to learning impacts upon their ability to reason clinically was a component of this present study.

### 3.3.4 Ethical Considerations

To ensure that this study complied with the standards of ethical research, a number of issues were considered. A research proposal for this Doctor of Philosophy (PhD), was approved by The University of Adelaide Human Research Ethics Committee (Approval Number H-61-2003). Students in first year of Medical School at The University of Adelaide in 2004 and 2005 were invited to participate in this project during Orientation Week. Students were informed about the study verbally and via the Information Sheet (see Appendix A) before being invited to sign two copies of the Consent Form (see Appendix A) in order to participate in this project. All students given the Information Sheet and Consent Form consented to be involved in this project. A sheet detailing how to lodge a complaint about the project with the Human Research Ethics Committee was also provided (see Appendix A). The researcher did not have any teaching or assessment responsibilities for any of the students involved in this study, and this will be the case for the duration of the students' medical education at the University of Adelaide.

## 3.4 AN OVERVIEW OF THE RESEARCH METHODS

In order to address the research questions in this study (see section 2.7), a number of approaches were used to collect data, including:

- The development and validation of an instrument to analyse student clinical reasoning - The Anderson Clinical Reasoning Rubric (TACRR) (see Chapter Four),
- Case studies of students using interviews, student assessment data and tutor reports (see Chapter Six),
- The development of a critical thinking instrument specifically for medical students - The Anderson Critical Thinking Test (TACTT) (see Chapter Five),
- Use of students' examination marks as a measure of their knowledge level, and
- Use of Biggs' Revised 2 Factor Study Process Questionnaire (R-SPQ-2F) to ascertain students' approaches to learning (Biggs, Kember and Leung, 2001).

The subjects involved in this research were first and second year medical students from the Medical School of the University of Adelaide. In order to gain insight into the development of clinical reasoning and how critical thinking ability, knowledge base and approaches to learning impact upon this reasoning, these students were studied over the subsequent two years. First year medical students were selected as subjects for this research because when examining the impact of critical thinking ability, knowledge base and approaches to learning on the development of clinical reasoning, it was logical to study students who had not had any formal medical education about how to learn, think or reason clinically. The time frame for this study was defined by the time available for completion of the Doctor of Philosophy program.

To enhance the trustworthiness of this research, further information about the instruments and categorizations used in this study and the ultimate research design will now be provided.

### 3.4.1 The Instruments Used in this Study

#### *3.4.1.1 Open Ended, Semi-Structured Interviews*

The case studies in this research involved interviews with students over a two-year period. Interviews are necessary when it is not possible to observe behaviour, feelings or how people interpret the world around them or when it is desirable to obtain data about a situation that cannot be replicated (Drescher, Warren and Norton, 2004; Miller and Glassner, 1997). Standardized, open-ended interviews were used in this study in order to minimise variance in answers introduced by the researcher. These interviews focussed on insight, discovery and interpretation of the factors affecting clinical reasoning development (see Chapter Six for the interview data). The interviews were particularistic, descriptive, heuristic and inductive (Merriam, 1988).

#### *3.4.1.2 Measures of Clinical Reasoning and Critical Thinking*

Given the limited number of instruments available for measuring undergraduate medical student clinical reasoning ability and critical thinking ability, the researcher aimed to develop valid and reliable tools with which to measure these entities (see Chapters Four and Five for extended discussion about the validity and reliability of TACRR and TACTT).

#### *3.4.1.3 A Measure of Knowledge*

Students' scores for the knowledge question included in TACRR (see Chapter Four) and their scores for the program's integrated Examinations A, B and C and at the end of each semester were used as a measure of their knowledge level at that point in time. The examinations were integrated and tested biomedical science knowledge in the format of multiple choice and short answer questions (Examination A), questions based on human prosections, pathology specimens or histological slides (Examination B) and modified essay questions (Examination C). TACRR was used to analyse the examination that tested clinical reasoning (the case analysis).

#### *3.4.1.4 A Measure of Approach to Learning*

The tool used to assess students' approaches to learning in this study was the R-SPQ-2F as it is a valid and reliable instrument that takes into account the learning environment (Biggs et al., 2001; Leung and Kember, 2003). The test is also simple and fast to administer. Combining students' results on the R-SPQ-2F and the data obtained during interviews produced a detailed picture about their approach to learning.

The R-SPQ-2F (see Appendix B) contains some items from the original SPQ deep and surface scales, some reworded items from the original SPQ and some entirely new items. The resulting 43 items of the R-SPQ-2F were tested on 229 questionnaires with the Reliability procedure of SPSS and the EQS program (with multivariate Lagrange Multiplier and Wald tests) (Biggs et al., 2001). The process of trial and revision through reduction of items was repeated for 2 cycles and resulted in the R-SPQ-2F (Biggs et al., 2001). The R-SPQ-2F has 2 factors (deep and surface learning) each with 10 items (Biggs et al., 2001).

The R-SPQ-2F was scored using Biggs et al.'s guidelines (2001), whereby students could score a maximum of 50/50 for deep items and 50/50 for surface items (Biggs et al., 2001). In this study, students were categorized as having a deep, surface or ill-defined (not polarized to either deep or surface) approach to learning according to the difference between their score for deep and surface items on the R-SPQ-2F (see Table 2). For example, if a student scored 37/50 on the deep items and only 13/50 on the surface items, they were categorized as having a deep approach to learning, as the difference between the scores is 24 (which is greater than 10 points). Those with a difference of ten points or less (less than two standard deviations from the mean) were categorized as having an "ill-defined" approach to learning.

### 3.4.2 Section Summary

Table 3 summarizes how the above instruments were used to provide information in order to answer the research questions. Table 4 summarizes the timelines and what type of data was collected from which participants in this study.

## 3.5 CHAPTER SUMMARY

This chapter has outlined the principles of the study design, explaining why both quantitative and qualitative approaches were employed to investigate the development of clinical reasoning. The context in which this study was conducted and the ethical approval process for this research has been described. An overview of the research methods and justification for the instruments used in this study has also been provided. Chapters Four and Five describe in detail the development, administration and analysis of the instruments used to measure clinical reasoning and critical thinking in this study. Chapter Six and Seven detail and discuss the results of this study, and in Chapter Eight conclusions are drawn, limitations of the study assessed and recommendations for further research are described.

Table 2: Approach to Learning Category according to R-SPQ-2F Score

| Approach to Learning Category | Score on R-SPQ-2F |
|---|---|
| Deep | The total score on deep items was greater than or equal to the total score on surface items by 10 points |
| Surface | The total score on surface items was greater than or equal to the total score on deep items by 10 points |
| Ill-defined | The difference between the total score for deep items and the total score for surface items was less than 10 points |

Table 3: Approaches Used to Provide Information For Each Research Question

| ***Question*** | ***Tool*** |
|---|---|
| *How can student clinical reasoning be measured?* | *TACRR*<br>*Case Studies** |
| *How do students' clinical reasoning abilities change as they progress through the program?* | *TACRR*<br>*Case Studies** |
| *What factors influence the development of student clinical reasoning ability?* | *TACRR*<br>*Case Studies**<br>*TACTT*<br>*Examination A*<br>*Examination B*<br>*Examination C*<br>*R-SPQ-2F* |
| *How can students' critical thinking ability be measured?* | *Development of TACTT* |
| *How do students' knowledge bases influence their clinical reasoning?* | *Examination A*<br>*Examination B*<br>*Examination C*<br>*TACRR*<br>*Case Studies** |
| *How do students' critical thinking abilities influence their clinical reasoning?* | *TACTT*<br>*TACRR*<br>*Case Studies** |
| *How do students' approaches to learning influence their clinical reasoning?* | *R-SPQ-2F*<br>*TACRR*<br>*Case Studies** |

* Case studies included PBL Tutor Reports, PBL Journals and Student Interviews

Table 4: Timing and Methods of Data Collection In This Study

| **Time of Data Collection** | **Method of Data Collection and Students from Whom Data Was Collected** | | | |
|---|---|---|---|---|
| | **2004-5 Year 1+2 Cohort** | **2004-5 Case Study Cohort** | **2005 Year 1 Cohort** | **2005 Year 1 Interview Cohort** |
| **February 2004** | R-SPQ-2F<br>TACTT | R-SPQ-2F<br>TACTT | | |
| **April 2004** | | PBL Tutor Report 1<br>PBL Journal<br>Interviews | | |
| **June 2004** | TACRR Case 1<br>Examination A<br>Examination B | TACRR Case 1<br>PBL Tutor Report 2<br>Examination A<br>Examination B | | |
| **August 2004** | | Interviews | | |
| **September 2004** | | PBL Tutor Report 3 | | |
| **October 2004** | R-SPQ-2F<br>TACTT | R-SPQ-2F<br>TACTT<br>PBL Tutor Report 4 | | |
| **November 2004** | TACRR Case 2<br>Examination A<br>Examination B | TACRR Case 2<br>Examination A<br>Examination B | | |
| **February 2005** | | | R-SPQ-2F<br>TACTT | R-SPQ-2F<br>TACTT |
| **April 2005** | | PBL Tutor Report 5 | TACRR Case 5<br>(Mock) | TACRR Case 5<br>(Mock) |
| **June 2005** | TACRR Case 3<br>Examination A<br>Examination B<br>Examination C | TACRR Case 3<br>PBL Tutor Report 6<br>Examination A<br>Examination B<br>Examination C | TACRR Case 6<br>Examination A<br>Examination B | TACRR Case 6<br>Examination A<br>Examination B |
| **August 2005** | | Interviews | | Interviews |
| **September 2005** | | PBL Tutor Report 7 | | |
| **October 2005** | R-SPQ-2F | R-SPQ-2F<br>PBL Tutor Report 8 | R-SPQ-2F<br>TACTT | R-SPQ-2F<br>TACTT |
| **November 2005** | TACRR Case 4<br>Examination A<br>Examination B<br>Examination C | TACRR Case 4<br>Examination A<br>Examination B<br>Examination C | TACRR Case 7<br>Examination A<br>Examination B | TACCR Case 7<br>Examination A<br>Examination B |

# CHAPTER FOUR - THE DEVELOPMENT OF AN INSTRUMENT TO MEASURE CLINICAL REASONING ABILITY

## 4.1 INTRODUCTION

Chapter Four describes the development of a clinical reasoning instrument and provides an analysis of the reliability and validity of this instrument based on results from pilot studies. At the end of each semester during 2004 and 2005, as part of their regular assessment, the first and second year medical students completed an examination question that was designed to test their clinical reasoning ability. The clinical reasoning instrument, The Anderson Clinical Reasoning Rubric (TACRR) was developed to more formally analyse this examination question and to make judgements about particular components of students' clinical reasoning.

## 4.2 THE DEVELOPMENT OF TACRR

### 4.2.1 Introduction

There were three phases to the development of TACRR, namely (1) development and validation of the clinical reasoning criteria, (2) pilot testing of the framework and analysis with medical educators, and (3) trialling the instrument with a student sample in order to establish its reliability. During the development phase, the instrument went through seven iterations which are summarised in the following section.

### 4.2.2 TACRR – Version 1

Based on the process of clinical reasoning described in section 1.1, thirteen criteria of clinical reasoning were established and became the framework for TACRR (see Table 5).

Table 5: The Initial Version of TACRR

| | The Anderson Clinical Reasoning Rubric | | Student | Name | | Student ID | Scores |
|---|---|---|---|---|---|---|---|
| 1 | How much of the relevant clinical information is identified? | All (5) | Most (4) | Some (3) | Little (2) | None (1) | |
| 2 | How well is the relevant clinical information prioritised in the student's hypotheses? | Extremely well (5) | Very well (4) | Well (3) | Poorly (2) | Not at all (1) | |
| 3 | How well is the relevant clinical information utilised with appropriate weighting in the student's hypotheses? | Extremely well (5) | Very well (4) | Well (3) | Poorly (2) | Not at all (1) | |
| 4 | How often are the detailed hypotheses logical? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 5 | How well do the hypotheses take into account epidemiological considerations? | Extremely well (5) | Very well (4) | Well (3) | Poorly (2) | Not at all (1) | |
| 6 | How often are hypotheses of mechanisms for symptoms correct? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 7 | How often are hypotheses of mechanisms for signs correct? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 8 | How often are hypotheses of mechanisms for investigations correct? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 9 | How often, when discussing ideas, are the steps in reasoning logical? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 10 | How often are individual steps in reasoning supported with relevant findings from this clinical case? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 11 | How often are the identified learning issues logical? | Always (5) | Most of the time (4) | Sometimes (3) | Hardly Ever (2) | Never (1) | |
| 12 | In supporting the clinical reasoning process, I judge this student's knowledge level to be… | Excellent (5) | Good (4) | Adequate (3) | Poor (2) | Very Poor (1) | |
| 13 | The student's overall approach to the problem is… | Excellent (5) | Good (4) | Average (3) | Poor (2) | Very Poor (1) | / 65 |

To ensure that the clinical reasoning criteria were contextually appropriate, they were validated by two experienced medical educators who had an understanding of this undergraduate PBL program. The rubric was designed to assess not only whether the student incorporated the relevant clinical information into their answer, but also how the student prioritised that information and whether they used it with appropriate weighting in their hypotheses. Assessment of how appropriate the student's hypotheses were and how much they analysed the epidemiological considerations of the case was also included. Correctly explaining the mechanism for a symptom, sign or investigation result displays a student's knowledge of physiological processes and basic science. To practise sound clinical reasoning requires a scientific knowledge base. Therefore, how logical the hypothesised mechanisms for symptoms, and/or signs, and/or investigations were was also important. Clinical reasoning also involves being able to apply knowledge to this case in particular: it is of no use for a student to have knowledge and not be able to apply it. Therefore, how often individual steps in reasoning were supported with relevant findings from the clinical case was also assessed. In order to learn the process of clinical reasoning in this PBL context, it is also important that a student can recognize when they lack an adequate knowledge base for working through a clinical case and be able to pinpoint the relevant knowledge needed in order to do so. Therefore, the student's ability to identify and express learning issues was also assessed by TACRR. As no one can reason without knowledge, TACRR included an overall judgement of the student's knowledge level. Finally, a global score reflecting the student's reasoning approach to the problem was included.

The rubric to analyse students' clinical reasoning was designed with explicit scoring rules as "raters can achieve good agreement in categorising errors provided they are given explicit scoring rules and do not rely solely upon clinical judgement" (Hasnain, Onishi and Elstein, 2004, p 606). Version 1 of TACRR is shown in Table 5. This version included 13 items which were linked to the clinical reasoning model for the PBL context, and each criterion was to be rated on a five point scale from five (all, extremely well, always or excellent) to one (not at all, never or very poor).

### 4.2.3 Instrument Review and Development

Due to the lack of a comparative standard of clinical reasoning with which to validate TACRR, a validation approach that included a peer review was implemented. The initial design of TACRR (Table 5) was reviewed by experienced medical educators and this resulted in further refinements. Each version of TACRR was used by the researcher and two medical educators to analyse independently a representative sample of student examination papers. In total, there were seven iterations of the instrument before agreement was reached about the wording and scoring of the criteria. A summary of the development of TACRR is described in Table 6. The developmental versions of TACRR are listed as tables in Appendix E. The final version of TACRR (Table 7) was then tested by independent experienced medical educators who had not been involved in the development process using de-identified student examination papers.

The main refinements during the development of TACRR included

- re-wording of the criteria to make them clearer,
- simplifying the scoring process and
- developing *The Rationale for TACRR* (see Appendices C and D) - a manual that explains how to use the instrument.

Re-wording of TACRR criteria included merging some criteria deemed to be assessing the same skill. For example, questions five, six and seven in the initial version (i.e. How often are the hypotheses for the mechanisms of symptoms correct? How often are the hypotheses for the mechanisms of signs correct? How often are the hypotheses for the mechanisms of investigations correct?) were merged in order to make question five in the final version (hypothesising correct mechanisms for the symptoms and/or signs and/or investigations in the case). This modification was necessary as reviewers commented that in each instance the assessor is making a judgement about the students' ability to demonstrate the application of their knowledge base, and this skill level was often found to be similar across students' mechanisms for symptoms, signs and investigations.

Table 6: Summary of the Development of TACRR

| Version of TACRR | Method of the Trial of this Version of TACRR | | Weaknesses in the version of TACRR | Key Changes Made after Trialing this Version of TACRR |
|---|---|---|---|---|
| | Number of Researchers | Number of Papers Analyzed | | |
| 1 | 3 | 15 | 1. Scoring scale was not user friendly – needed to be broader<br>2. Questions 2 and 3 were very similar<br>3. Too large a gap between categories of "well" and "poorly" | 1. Scoring scale 0-5, not 1-5<br>2. Questions 2 and 3 merged<br>3. New category of "very poorly" |
| 2 | 3 | 15 | 1. Unclear as to how to award marks for the questions<br>2. Questions 5, 6 and 7 could be merged as they addressed the mechanism section of the paper<br>3. One could have little knowledge but still perform well on TACRR. | 1. The Rationale Behind TACRR Manual produced (see Appendix C)<br>2. Weightings of the questions made to reflect the importance of knowledge for clinical reasoning: questions 2, 3 6, and 7 now worth 10 marks, and question 5 now worth 15 marks. |
| 3 | 3 | 5 | 1. Being forced to award students marks in categories did not allow markers to accurately indicate a student's ability<br>2. Individual questions were too wordy<br>3. Learning issues in question 8 need to be "useful", not "logical"<br>4. The knowledge level required in question 9 needs to be qualified<br>5. Knowledge is important for clinical reasoning and as question 9 marks for knowledge it should be weighted accordingly | 1. Any number of marks up to an individual maximum for each TACRR question could be awarded to a student, with no prescribed categories<br>2. The Rationale Behind TACRR Manual had the new marking scheme<br>3. "Please award up to a maximum of 10 marks for the student's performance in each of the following areas…" instructions put at the top of TACRR to make individual questions less wordy<br>4. Question 8 changed to "useful" learning issues<br>5. Question 9 qualified as the "knowledge of a year 1 medical student"<br>6. Total marks allowed for question 9 increased from 5 to 10 |
| 4 | 3 | 5 | 1. Epidemiological considerations are less important than illness timelines<br>2. It was unclear which part of the examination paper corresponded to which section of TACRR<br>3. Learning issues reflect knowledge and therefore question 8 is an important TACRR section<br>4. Knowledge is very important for clinical reasoning and this should be reflected in the weighting of question 9<br>5. One's overall approach to the paper is an important indicator of clinical reasoning and therefore question 10 should be weighted as such | 1. The epidemiological question 4 of TACRR 4 was replaced with a timeline question<br>2. The Rationale Behind TACRR Manual included which part of the examination paper should be examined for the individual TACRR sections<br>3. A maximum of 10 rather than 5 points could be awarded for question 8<br>4. A maximum of 15 rather than 10 points could be awarded for question 9<br>A maximum of 10 rather than 5 points coulc be awarded for question 10 |
| 5 | 3 | 3 | 1. Inter-rater reliability may be increased by discussing an examination answer and reaching a consensus before marking the papers<br>2. Hypotheses need to be "appropriate" more than "logical" | 1. A consensus about the ideal answer to the examination question was reached by the markers before analysing the papers<br>2. The Rationale For TACRR Manual was updated with how hypotheses can be scored as appropriate rather than just logical (see Appendix D) |
| 6 | 3 | 3 | 1. There is no statistical evidence for use of differential weightings in tests | 1. Differential weightings of TACRR sections removed |

Table 7: Final Version of TACRR

| | **The Anderson Clinical Reasoning Rubric (TACRR)** | |
|---|---|---|
| | Please award up to a maximum of 10 marks for the student's performance in each of the following areas… | Score |
| A1 | Identifying the relevant clinical information in the case by incorporating it into an hypothesis. | /10 |
| A2 | Utilising the relevant clinical information in the case with appropriate weighting in the hypotheses. | /10 |
| A3 | Detailing appropriate hypotheses. | /10 |
| A4 | Taking into account the timeline considerations inherent in the case in the hypotheses. | /10 |
| B5 | Hypothesising correct mechanisms for the symptoms and/or signs and/or investigations in the case. | /10 |
| C6 | In hypotheses and/or mechanisms, discussing ideas using logical steps in reasoning. | /10 |
| C7 | In hypotheses and/or mechanisms, supporting individual steps in reasoning with relevant clinical information from the case. | /10 |
| D8 | Identifying useful learning issues. | /10 |
| E9 | Demonstrating a medical knowledge of the issues in the case at a level appropriate for a student's year of medical school. | /10 |
| E10 | The student's overall approach to the clinical case. | /10 |
| | TOTAL OUT OF 100 MARKS | /100 |

One of the issues in developing TACRR was the weighting of criteria. During the development, where different clinical reasoning criteria were deemed to be more important to the overall process than others, the questions were weighted accordingly. For instance, although both are useful for clinical reasoning, medical knowledge was deemed to be more important than being able to identify symptoms. For this reason, in version 6 of TACRR (Table E5 in Appendix E), students could be awarded up to a maximum of only 5 marks for question one (identifying the relevant clinical information in the case by incorporating it into an hypothesis) but up to a maximum of 15 marks for question nine (demonstrating a medical knowledge of the issues in the case at a level appropriate for a Year 1 student). During the review of TACRR, it was found that assessors struggled with the process of using differential weightings. In addition, after reviewing the literature, it was reported that statisticians consider that differential weighting of questions does not have significant benefit (Frary, 1989; Guilford, 1954; Gulliksen, 1950; Wang and Stanley, 1970). Subjectivity in assigning weightings can lead to decreased reliability (Frary, 1989). Differential weighting of questions often results in the same rank order of student scores and does not consistently enhance the psychometric quality of test scores unless there is an issue of internal consistency (Frary, 1989). When TACRR scores for student papers marked with a weighted version were compared with scores for the same student papers marked with a non-weighted version, there was no significant difference in the scores. Thus in the final version, the maximum score for each criterion was set at ten.

It can be argued that making learning issues is not a skill involved in clinical reasoning, but instead a separate, albeit related, skill. As explained in *The Rationale For TACRR* (Appendix D), making learning issues for clinical reasoning involves a person reflecting upon their knowledge, recognising that she or he lacks adequate knowledge in a particular area, and being able to pinpoint what knowledge is required for the situation. However, as making learning issues is an integral part of students developing applicable knowledge bases that they can then use to reason clinically, it was felt important to analyse this skill as part of the investigation of clinical reasoning development. For this reason, a question about the quality of the student's learning issues was included in TACRR.

In order to make the clinical reasoning instrument more reliable, a manual, *The Rationale For TACRR*, was developed (Appendix D). This manual explains in detail the performance expected in order for a student to be awarded marks for the criteria in the final version of TACRR, and to minimise discrepancies between the marks awarded by assessors for the same standard of clinical reasoning. These levels of performance were reviewed as part of the development process. *The Rationale For TACRR* (Appendix D) also outlines that the instrument's questions are divided into sections A to E (Table 7) according to the parts of the case analysis that are to be examined in order to award marks for the students' performance. The ability to aggregate scores for the questions in a section gives additional information about the students' performance on different components of a case analysis.

All of the refinements made to TACRR resulted in the final version of the instrument as illustrated in Table 7. This was the version of the instrument used in this present study.

## 4.3 INTRA- AND INTER-RATER RELIABILITY OF TACRR

To test the inter-rater reliability of TACRR, six archived examination papers (a selection of good, borderline and weak papers, as categorised by their Medical School marks for the examination) were randomly selected by an independent party. After de-identification, these examination papers, *The Rationale For TACRR* and a 'model answer' to the examination were supplied to two experienced medical educators who taught in the University of Adelaide Medical School and who were familiar with the clinical reasoning approach used in the PBL program. These experienced medical educators had not been involved in the development process and independently assessed the six student papers using the final version of TACRR. There was a strong correlation between independent researchers' analysis scores for the six examination papers (Pearson product-moment correlation coefficient $r = 0.84$, $p < 0.05$), suggesting that the instrument has high inter-rater reliability.

The intra-rater reliability of this clinical reasoning instrument was also evaluated. In order that the researcher did not recognise the papers and remember how they had been scored, an independent party randomly selected ten examination papers completed by first year medical students in June 2004 (a selection of very good, good, borderline and weak papers). In April 2005, the researcher then used TACRR to re-analyse these examination papers. There was a strong correlation between the initial scoring for the students' questions, and the re-test scoring by the same researcher a year later (Pearson product-moment correlation coefficient $r = 0.81$, $p < 0.01$).

Further evidence for TACRR's reliability was provided by testing its internal consistency through using the instrument to score first year medical student examination papers. 145 first year medical students' (84 female and 61 male students) Semester 1 examination papers were analysed. The clinical scenario and examination questions are outlined in Figure 1. Student clinical reasoning performance as rated for this test sample ($N = 145$) is summarised in Table 8.

The Cronbach Alpha coefficient is a measure of the internal consistency or reliability of an instrument. Ideally the Cronbach Alpha value should be above 0.7. TACRR proved to have satisfactory internal consistency with a Cronbach alpha coefficient of 0.94 ($N = 145$). However, the content specificity of clinical reasoning cases means that testing TACRR using more clinical scenarios would be wise. Also, the students' scores for each question clustered around the mid-point, which lessens the discriminatory ability of TACRR.

## 4.4 CHAPTER SUMMARY

This chapter describes the design and development of TACRR. This instrument has undergone rigorous peer review for validation and has internal consistency, good inter-rater reliability and good intra-rater reliability. The development of TACRR allows measurement of student clinical reasoning in the context of an integrated PBL-program, and provides data for the research question "How can student clinical reasoning ability be measured?".

Dan Bush is a 20-year old student at University of South Australia. He presents to his local doctor, during his end of year examinations, complaining of diarrhoea for the last 3 weeks. He says he has been passing 6-7 small semi-fluid motions each day since the attack began. The motions are normal in colour but contain bright blood and mucus. He gets bouts of abdominal pain just before he has to have a bowel action. This pain is located in the lower abdomen, more on the left side than the right. It tends to come on shortly before he has to have his bowels open and he has also experienced discomfort in his rectum at this time, along with some urgency to pass a motion once the pain occurs. The pain is relieved, for the time being, by having a bowel action. His appetite has been only fair during this time, and he "has not been feeling 100%". He has not been nauseated and has not vomited. He has not had a temperature, but from time to time has been "feeling a bit hot and sweaty", mainly when he gets the pain. He acknowledges that he is "pretty worried" about his end of year examinations, which are about to begin. His health through the year has been good and he played football "in the seconds". He has not been outside Adelaide during the year. He has no previous serious illness. On questioning he recalls that he had a similar but less severe attack of abdominal pain and diarrhoea, during the matriculation examinations, but that attack was not so severe as this and he did not notice any blood or mucus at that time. He saw his local doctor and recalls that he had a rectal examination, which was both uncomfortable and painful at that time. The attack lasted only for 2 weeks and settled down quickly with some anti-diarrhoeal medicine, which his doctor prescribed. No specific diagnosis was made at that time and no further investigations were undertaken. He also had loose motions for a couple of days before the exams in the mid-year. He is worried about the effect the illness is having on his exam preparation.

Analyse the data you are given and prepare a short LIST (3-5) of hypotheses. Provide evidence from the data for each hypothesis.

For EACH hypothesis, outline briefly the important mechanism(s) involved in producing the clinical features you chose in part 1.

For each hypothesis/mechanism indicate the learning issues you consider will prepare you and be most helpful to you for answering more detailed questions about the patient and for explaining the mechanisms responsible for his abnormal clinical features. Indicate (with an *) those learning issues which you consider you already have sufficient prior knowledge.

Figure 1: Case 1 Examination Paper

Table 8: TACRR Scores for First Year Medical Student Examination Papers

| | **TACRR Section** | **Mean Score (%) of All Students (*N* = 145)** | **Standard Deviation of All Students (*N* = 145)** |
|---|---|---|---|
| 1 | Identifying the relevant clinical information in the case by incorporating it into an hypothesis. | 63 | 13 |
| 2 | Utilising the relevant clinical information in the case with appropriate weighting in the hypotheses. | 62 | 18 |
| 3 | Detailing appropriate hypotheses. | 54 | 22 |
| 4 | Taking into account the timeline considerations inherent in the case in the hypotheses. | 42 | 24 |
| 5 | Hypothesising correct mechanisms for the symptoms and/or signs and/or investigations in the case. | 48 | 17 |
| 6 | In hypotheses and/or mechanisms, discussing ideas using logical steps in reasoning. | 55 | 16 |
| 7 | In hypotheses and/or mechanisms, supporting individual steps in reasoning with relevant clinical information from the case. | 61 | 15 |
| 8 | Identifying useful learning issues. | 52 | 19 |
| 9 | Demonstrating a medical knowledge of the issues in the case at a level appropriate for a Year 1 student. | 52 | 15 |
| 10 | The student's overall approach to the clinical case. | 55 | 16 |

# CHAPTER FIVE - THE DEVELOPMENT OF AN INSTRUMENT TO MEASURE CRITICAL THINKING ABILITY

## 5.1 INTRODUCTION

In order to measure medical students' critical thinking ability and compare it with their clinical reasoning, an instrument to measure critical thinking (The Anderson Critical Thinking Test (TACTT)) was developed. As described in section 2.6.2, there is a lack of available valid, reliable and affordable critical thinking tests which can be applied in a medical education context (Ennis, 1993). This chapter describes the development of TACTT and reports on its validity and reliability.

## 5.2 DESIGNING TACTT

TACTT was developed to measure many of the critical thinking skills detailed in The American Philosophical Association Delphi Research Report (Table 1, page 22) (Facione, 1990).

In order for the test to be interesting to commencing medical students, questions related to the medical context were developed for TACTT. The questions were similar in format to those on the Watson Glaser Critical Thinking Appraisal (WGCTA), and were designed to test students' ability to interpret, analyse, evaluate and make inferences from given information, according to the critical thinking sub-skills outlined in Table 1 (page 22). The skills of explanation and self-regulation were not tested by TACTT, as it was deemed too difficult to test these attributes in a questionnaire format. The instrument was designed to have a number of questions testing the same critical thinking cognitive skill. The original version of the test had 43 questions (Appendix F). After refinement (see below), the final version of the test had 38 questions and students could complete this test in 45 minutes.

## 5.3 INSTRUMENT REVIEW AND DEVELOPMENT

### 5.3.1 Peer Review

The 43 questions in the original version of TACTT are outlined in Figure 2. The answers to the questions are given in brackets. The complete original version of TACTT, including details and student instructions, is provided in Appendix F.

The original version of TACTT was reviewed by two medical educators, a psychologist and a general practitioner with experience in test construction. Both the psychologist and general practitioner contributed to the development of the Undergraduate Medicine and Health Sciences Admission Test (UMAT). This is a nationally administered instrument that students are required to take in order to gain selection into health-orientated courses at many Australian universities. Each person analysing TACTT was given a copy of the test, a copy of Table 1 (on which the test was based) and an explanation of the critical thinking skills each question was designed to measure. These people were then asked to provide written feedback, including information about how the test instructions could be made clearer, how the wording of the questions could be changed to make them less ambiguous, how the layout of the test could be improved, and whether each question measured the critical thinking cognitive sub-skill for which it was designed.

As a result of this peer review of the critical thinking instrument, the wording of some question stems was changed (e.g. Item A from the Interpretation section) to make it less ambiguous and some questions were removed entirely (e.g. Item M from the Inference section). The order of the questions was changed so that the answers to the questions did not follow a pattern and to decrease the possibility of students guessing the right answers. The reviewers considered it a strength of the test that it contained some emotionally charged questions (e.g. Item I from the Evaluation section) as this would help to distinguish those students who were able to analyse and evaluate the logic of the question objectively (think critically), from those who were distracted by the question content. It was agreed by reviewers that TACTT had good face validity and that as it did not test subject-specific knowledge and was relatively simple, it would be inviting for most medical students to complete.

It was recognised by the reviewers that much of TACTT required the application of verbal critical thinking skills rather than non-verbal critical thinking skills. Therefore, the original version was also critiqued by a lecturer in the Language and Learning in Medicine Program at the University of Adelaide Medical School. This person had expertise in critical literacy, linguistics and inter-cultural

**Section 1 (Interpretation)**
**a = DOES follow logically, b = DOES NOT follow logically**

A. Today, electroconvulsive therapy (ECT) involves electrically inducing a brief generalised seizure of adequate intensity after administration of a short-acting general anaesthetic and muscle relaxant. ECT became popular as a method to treat psychiatric illnesses in the 1930s, and it continued to be widely used until the 1970s, when the use of pharmacological treatments increased.

1. ECT was not widely used until 1930.(a)
2. ECT was not popular until after 1970.(b)
3. Pharmacological treatments were not used for psychiatric illnesses before 1930.(b)

B. Compliance can be defined as "the extent to which the patient's behaviour coincides with medical advice". Non-compliance with medication is a major problem and may have serious consequences for patient health and wellbeing. However, no readily observable characteristics of poorly compliant patients permit their easy identification.

4. If the patient does not think like a doctor, they are non-compliant.(b)
5. If a patient does not take the medication the doctor prescribes, their health and wellbeing is in danger.(b)
6. There is no way to identify poorly compliant patients.(b)

**Section 2a (Analysis)**
**a = Assumption WOULD be made, b = Assumption WOULD NOT be made**

C. Even lazy interns require stamina to work the many hours required of them in the hospital.

7. All interns require stamina.(a)
8. Only lazy interns are required to work long hours at the hospital.(b)
9. Interns that are not lazy do not require stamina.(b)

D. People who suffer from diabetes should avoid eating chocolate, icecream and lollies as these foods contain sugar.

10. People who suffer from diabetes should avoid eating sugar.(a)
11. People who suffer from diabetes should avoid eating sweet things.(b)
12. People not suffering from diabetes do not need to be concerned about what they eat.(b)

Figure 2: Questions in the Original Version of TACTT

**Section 2b (Analysis)**
**a = DOES follow logically, b = DOES NOT follow logically**

E. Some medical students are musical. All medical students are smart. Therefore

13. Some musical medical students are smart.(b)
14. Some smart people are musical.(a)
15. No smart people are musical.(b)

F. All good medical textbooks are expensive. All good medical textbooks are worth buying. Therefore

16. Whatever is worth buying is expensive.(b)
17. Some expensive things are worth buying.(a)
18. There are many different things worth buying.(b)

G. Some doctors who are working long hours are enthusiastic about being required to teach medical students. Only young physicians are required to work long hours. Therefore

19. Some young physicians are enthusiastic about being required to teach medical students.(a)
20. Some doctors enthusiastic about being required to teach medical students are not young physicians.(b)
21. A person cannot be enthusiastic about being required to teach medical students and be a young physician.(b)

**Section 3 (Evaluation)**
**a = STRONG argument, b = WEAK argument**

H. Should electroconvulsive therapy (ECT) be used to treat psychiatric illnesses?

22. Yes; ECT has been shown to be more effective that some antidepressants for major depression, and to be as effective as some medications for acute schizophrenia and mania.(a)
23. No; ECT has side effects.(b)
24. No; ECT is an old treatment that has been used since before 1930.(b)

I. Should every patient who suffers a stroke have their license revoked?

25. Yes; Having had a stroke means that some people cannot perform the movements necessary to drive a vehicle.(a)
26. No; It is unfair to remove somebody's license because of a medical condition.(b)
27. No; People who suffer strokes are a burden on their carers if they cannot drive themselves anywhere.(b)

J. Should medical students be required to do research as part of their training?

28. No; Students should concentrate on becoming clinically competent doctors – if they want to do research they should do a different degree.(b)
29. Yes; Studies have shown that those students who engage in research become better doctors.(a)
30. No: Students should have the option to do research but it should not be compulsory as it is not a necessary part of becoming a doctor.(a)

Figure 2: Questions in the Original Version of TACTT (Continued)

**Section 4 (Inference)**
**a = DEFINITELY TRUE**
**b = PROBABLY TRUE**
**c = PROBABLY FALSE**
**d = DEFINITELY FALSE**
**e = INSUFFICIENT DATA**

K. Many students volunteer to be involved in drug trials as a way of earning money. Usually healthy young males are selected. Sometimes the trials involve staying in hospital overnight. Other times the people being studied have to have a blood test or give a urine sample. It is wise to know what the trial involves before volunteering to be a part of it.

31. Students volunteering to be involved in drug trials are motivated to do so for the monetary gain.(b)
32. Most people involved in drug trials are over 40 years old.(d)
33. Most people involved in drug trials are international students.(d)
34. All drug trials involve having a blood test or giving a urine sample.(d)
35. Some students see temporary hospitalisation as worthwhile.(a)

L. Many doctors are faced with the task of breaking bad news to patients. How one breaks bad news to a patient can have a huge impact on the way that they respond to that information. Some people argue that many doctors do not have good communication skills. Good communication skills can be learned over time.

36. Teaching doctors communication skills would not alter the way patients respond to bad news.(c)
37. Some general practitioners do not have good communication skills.(b)
38. You are born with good communication skills: you either have them or you do not have them.(d)
39. All medical schools should endeavour to teach communication skills.(b)

M. Some people get severely injured at work. Studies have shown that those people on Workcover recover much more slowly than those who are not on Workcover. Not many people who are self-employed are able to go on Workcover.

40. Those who do not have an alternate source of income return to work sooner than those covered by Workcover.(a)
41. People who do not get severely injured at work recover faster than those who do.(e)
42. Having Workcover is a hindrance as it prevents people from returning to work.(d)
43. If Workcover did not exist, self-employed people would recover from a workplace injury at the same rate as those employed by someone other than themselves.(b)

Figure 2: Questions in the Original Version of TACTT (Continued)

communication. This linguistics expert provided feedback on how the instructions for TACTT could be made clearer and she also suggested including a graphical section to test some non-verbal critical thinking skills.

An independent researcher and consultant in Educational Psychology with experience in test analysis and assessment and evaluation in the United States of America also reviewed the original version of TACTT. As a result of this researcher's feedback, the instructions at the beginning of each section of the test were simplified and shortened. The layout of the test was also changed to incorporate an answer column on the right hand side of the page, rather than have students fill out a separate answer sheet. This was done in an effort to simplify the answering of the test and remove a possible error influence not related to the critical thinking issue. It was also suggested that the answers reading "Y" and "N" for "yes" and "no" rather than making students do the conversion "yes, the conclusion follows logically = a" and "no, the conclusion does not follow logically = b", would simplify answering the test. The different sections of TACTT were also re-ordered so that sections with similar response styles were together and the graphical section was placed at the end of the test.

The original version of TACTT was piloted on seven 2003 first year medical students. This was done in order to test the questionnaire construction. The same information and consent procedures were used for this exercise as for the major project (see Appendix A), but with documentation that it was a test of the questionnaire construction only. Students were allowed to ask questions about the test instructions as they completed TACTT over 45 minutes and they then provided verbal feedback to the researcher after having done the test. This pilot study provided valuable information about how to make the instrument instructions clearer and how to change the test layout in order to make it easier to understand.

### 5.3.2 The Final Version of TACTT

The final version of TACTT was designed with five sections, each with a separate set of instructions. Table 9 outlines the critical thinking skills tested in each section and what was required in order to answer the questions in these sections of the instrument. The core questions of the final version of TACTT are listed in Figure 3 below with their answers (see Appendix G for the actual test).

Table 9: Critical Thinking Skills Tested by Sections of TACTT and What Was Required in Order to Answer the Questions in These Sections

| **TACTT Section (Critical Thinking Skills Being Tested)** | **Questions in This Section** | **What was Required in Order to Answer the Questions** |
|---|---|---|
| Section 1<br><br>(Interpretation and Evaluation) | 1 - 6 | The significance of the information had to be decoded and its meaning clarified in order to decide whether a conclusion followed logically from the information given. |
| Section 2<br><br>(Analysis) | 7 - 15 | Information had to be examined in order to identify the arguments presented and therefore decide whether a conclusion followed logically from the information given. |
| | 16 - 21 | Statements had to be examined and arguments analysed in order to decide whether an assumption would or would not be made by the person making the given statement. |
| Section 3<br><br>(Evaluation) | 22 - 30 | Arguments had to be evaluated in order to assess whether they were strong or weak. |
| Section 4<br><br>(Inference) | 31 - 35 | Conclusions had to be drawn, evidence queried and alternatives to the given information conjectured in order to decide whether an inference was definitely true, probably true, probably false, definitely false or whether there was insufficient data for this decision to be made. |
| Section 5<br><br>(Interpretation and Evaluation) | 36 - 38 | Data in a graph had to be gathered, its significance decoded and its meaning clarified in order to assess claims based on information presented in a graphical form. |

**Section 1 (Interpretation and Evaluation)**
**Y = Yes: Conclusion DOES follow logically**
**N = No: Conclusion DOES NOT follow logically**

A. Electroconvulsive therapy (ECT), became popular as a method to treat psychiatric illness in the 1930s. ECT continued to be widely used until the 1970s, when the use of drug treatments increased.

| | | |
|---|---|---|
| 1. | ECT was not widely used until 1930. | **Y** |
| 2. | ECT was not popular until after 1970. | **N** |
| 3. | Pharmacological treatments were not used for psychiatric illnesses before 1930. | **N** |

B. Compliance can be defined as "the extent to which the patient's behaviour coincides with the doctor's advice". Non-compliance with taking regular medication is a major problem and may have serious consequences for patient health and wellbeing. However, poorly compliant patients are not easily identified.

| | | |
|---|---|---|
| 4. | If the patient does not think like a doctor they are non-compliant. | **N** |
| 5. | If a patient does not take the medication the doctor prescribes, their health and wellbeing may be adversely affected. | **Y** |
| 6. | There is no way to identify poorly compliant patients. | **N** |

**Section 2a (Analysis)**

C. Some medical students are musical. All medical students are smart. Therefore

| | | |
|---|---|---|
| 7. | only some musical medical students are smart. | **N** |
| 8. | no smart people are musical. | **N** |
| 9. | some smart people are musical. | **Y** |

D. All good medical textbooks are expensive. All good medical textbooks are worth buying. Therefore

| | | |
|---|---|---|
| 10. | whatever is worth buying is expensive. | **N** |
| 11. | some expensive things are worth buying. | **Y** |
| 12. | there are many different things worth buying. | **N** |

E. Some doctors who work long hours are enthusiastic about being required to teach medical students. Only young physicians work long hours. Therefore

| | | |
|---|---|---|
| 13. | some young physicians are enthusiastic about being required to teach medical students. | **Y** |
| 14. | some doctors enthusiastic about being required to teach medical students are not young physicians. | **N** |
| 15. | a person cannot be enthusiastic about being required to teach medical students and be a young physician | **N** |

Figure 3: Questions in the Final Version of TACTT

**Section 2b (Analysis)**

F. Even lazy interns require stamina to work the many hours required of them at the hospital.

16. Only lazy interns are required to work long hours at the hospital. **N**
17. All interns require stamina. **Y**
18. Interns who are not lazy do not require stamina. **N**

G. People who suffer from diabetes should avoid eating chocolate, icecream and lollies as these food items contain sugar.

19. People who suffer from diabetes should avoid having sugar in their coffee. **Y**
20. People who suffer from diabetes should avoid eating sweet things. **N**
21. People not suffering from diabetes do not need to be concerned about what they eat. **N**

**Section 3 (Evaluation)**

**S = STRONG argument**
**W = WEAK argument**

H. Should electroconvulsive therapy (ECT), be used to treat psychiatric illnesses?

22. No; ECT is a very old treatment. **W**
23. No; ECT has side effects. **W**
24. Yes; ECT is an internationally recognised psychiatric treatment. **S**

I. Should every patient who suffers an epileptic seizure have their license suspended?

25. No; It is unfair to remove someone's license because of a medical condition. **W**
26. Yes; Having had a seizure means that someone is not safe to drive a vehicle. **S**
27. No; People who suffer from epilepsy are a burden on their carers if they cannot drive themselves anywhere. **W**

J. Should medical students be required to do research as part of their training?

28. No; Students should concentrate on becoming clinically competent doctors – if they want to do research they should be doing a different degree. **W**
29. Yes; studies have shown that those students who engage in research become better doctors. **S**
30. No; Students should have the option to do research but it should not be compulsory as it is not a necessary part of becoming a doctor. **S**

Figure 3: Questions in the Final Version of TACTT (Continued)

**Section 4 (Inference)**

**A = DEFINITELY TRUE**
**B = PROBABLY TRUE**
**C = PROBABLY FALSE**
**D = DEFINITELY FALSE**
**E = INSUFFICIENT DATA**

K. Many students volunteer to be involved in drug trials as a way of earning money. Usually healthy young males are selected. Sometimes the trials involve staying in hospital overnight. Often the people being studied have to have a blood test or give a urine sample. It is wise to know what the trial involves before volunteering to be a part of it.

| | | |
|---|---|---|
| 31. | Students volunteering to be involved in drug trials are motivated to do so for the monetary gain. | **B** |
| 32. | Most people involved in drug trials are over 40 years old. | **D** |
| 33. | Some students are prepared to be temporarily hospitalised in order to earn money. | **A** |

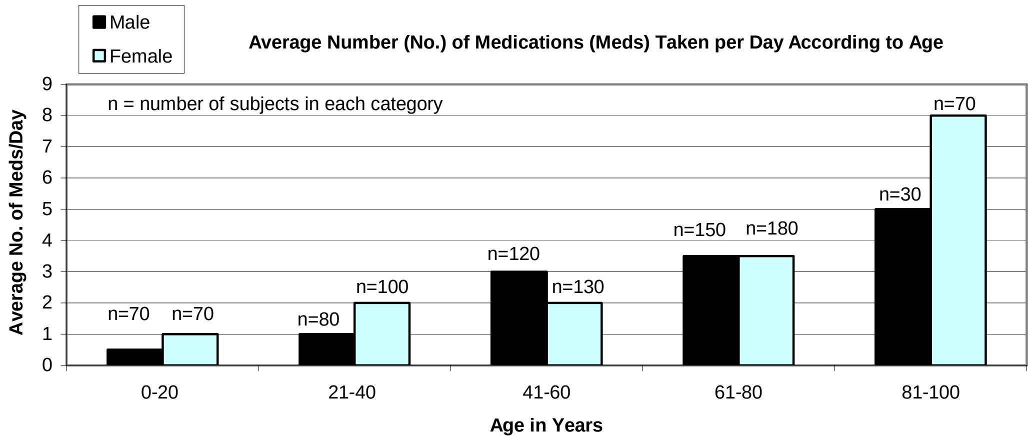
L. Many doctors are faced with the task of breaking bad news to patients. How a doctor breaks bad news to a patient can have a huge impact on the way that they respond to that information. Many doctors do not have good communication skills. Good communication skills can be learned over time.

| | | |
|---|---|---|
| 34. | Some general practitioners do not have good communication skills. | **B** |
| 35. | You are born with good communication skills: you either have them or you do not have them. | **D** |

Figure 3: Questions in the Final Version of TACTT (Continued)

**Section 5 (Interpretation and Evaluation)**

M.




36. In which age bracket is there the smallest difference between the average number of tablets taken per day by males and the average number of tablets taken per day by females?

| 0-20 years | 21-40 years | 41-60 years | 61-80 years | 81-100 years |
|---|---|---|---|---|
| A | B | C | D* | E |

37. How many women aged 21-40 years old take 1 tablet per day?

| 100 women | 50 women | 80 women | Cannot tell from given data |
|---|---|---|---|
| A | B | C | D* |

38. What percentage (%) of the people taking an average of 2 or fewer medications per day are male?

| 33% | 25% | 67% | 75% |
|---|---|---|---|
| A* | B | C | D |

Figure 3: Questions in the Final Version of TACTT (Continued)

The five sections of TACTT tested the critical thinking skills of interpretation, analysis, evaluation, and inference in verbal form (Sections 1, 2, 3 and 4, respectively) and the critical thinking skills of interpretation and evaluation in graphical form (Section 5). Each question was worth one mark and subjects could be awarded up to a maximum total of 38 marks. The scores for the individual sections 1 to 5 were the sum of the marks awarded for the questions in that section (up to a maximum of 6, 15, 9, 5 and 3 marks for each section, respectively).

**5.4 TRIALLING TACTT**

Two cohorts of first year medical students were invited to complete TACTT during Week 1, Semester 1 and at the end of Semester 2 in both 2004 and 2005, after having read an information sheet (Appendix A) and signed a form (Appendix A) consenting to participate in the study. In Week 1, Semester 1, 2006, a cohort of Science students at the University of Adelaide was also invited to complete TACTT, in order to further validate the instrument. The same information procedure was used for this latter exercise as for the major project (see Appendix A), but with documentation that it was a test of the questionnaire's construction only. Each cohort of students was given up to an hour to complete the test if necessary. Student cohorts' average scores for each section of TACTT and their average total score were converted to percentages and are reported in Table 10.

When tested on first year medical student cohorts of up to 129 subjects, the Cronbach alpha coefficient for the instrument ranged from 0.23 to 0.67 (see Table 10). Students in all cohorts performed best at interpretation (Section 1) followed by analysis (Section 2) and then evaluation (Section 3). Students from all cohorts were least proficient at inference and graphical interpretation and evaluation (Sections 4 and 5, respectively). However, in contrast to the Science student cohort, all of the Medical student cohorts were much better at graphical interpretation and evaluation (Section 5) than inference (Section 4). According to TACTT, of all the critical thinking skills tested, inference was the most difficult for medical students.

Table 10: Year 1 Cohort Average TACTT Percentage Scores for Critical Thinking Abilities

| | | Average TACTT Percentage Score for Critical Thinking Abilities (Standard Deviation) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year 1 Cohort** | **N** | **Section 1 Interpret and Evaluate** | | **Section 2 Analyse** | | **Section 3 Evaluate** | | **Section 4 Infer** | | **Section 5 Interpret and Evaluate** | | **Total Overall Critical Thinking** | | **Cronbach Alpha** |
| Medicine Feb 2004 | 129 | 88.5 | (15.4) | 83.5 | (10.5) | 73.0 | (15.0) | 53.2 | (21.0) | 66.7 | (30.6) | 76.4 | (8.8) | 0.45 |
| Medicine Feb 2005 | 104 | 90.9 | (13.7) | 84.7 | (10.2) | 74.9 | (12.9) | 56.9 | (21.9) | 71.2 | (28.3) | 78.6 | (7.9) | 0.23 |
| Science Feb 2006 | 92 | 90.2 | (13.1) | 88.5 | (8.1) | 77.3 | (12.3) | 68.0 | (19.7) | 67.4 | (31.6) | 80.6 | (9.2) | 0.67 |
| Medicine Oct 2004 | 111 | 88 | (15.4) | 83.3 | (10.4) | 73.2 | (17.0) | 55.5 | (21.5) | 68.8 | (29.9) | 76.8 | (9.6) | 0.53 |
| Medicine Oct 2005 | 104 | 88 | (16.3) | 84.4 | (13.6) | 74.9 | (16.2) | 55.6 | (21.4) | 72.8 | (31.1) | 78.0 | (11.5) | 0.65 |

Using this critical thinking instrument, the student cohorts achieved very high average total percentage scores and the range of scores did not follow a normal distribution as the Kolmogorov-Smirnov statistic significance was less than 0.05 for each cohort (Table 11), suggesting violation of the assumption of normality. As researchers have noted, "medical students represent a highly selected and atypical group, which has already demonstrated its skill in performing successfully in academic settings" (Dolmans and Wolfhagen, 2004, p.801). Given this fact and the TACTT scores, it was concluded that this instrument was not sensitive enough to identify the subtle grades of critical thinking ability present within this highly selected group. However, when TACTT was administered to a group of first year science students at The University of Adelaide, their range of scores were very similar in that they did not follow a normal distribution and the student cohort also achieved very a high average total TACTT percentage scores (Table 11). This provided further confirmation that TACTT was not a sensitive test of university students' critical thinking ability.

Table 11: Total TACTT Percentage Scores for First Year Student Cohorts

| **Function of Cohort's Total TACTT Percentage Score** | **2004 Medical Students** | | **2005 Medical Students** | | **2006 Science Students** |
|---|---|---|---|---|---|
| | **Semester 1 N = 127** | **Semester 2 N = 111** | **Semester 1 N = 105** | **Semester 2 N = 103** | **Semester 1 N = 92** |
| Average | 76.4 | 76.8 | 78.7 | 78.7 | 80.6 |
| Standard Deviation | 8.8 | 9.6 | 7.9 | 9.1 | 9.2 |
| Maximum | 89.5 | 94.7 | 97.4 | 94.7 | 94.7 |
| Minimum | 36.8 | 36.8 | 57.9 | 50.0 | 55.3 |
| Mode | 78.9 | 78.9 | 81.6 | 84.2 | 86.8 |
| Significance of Kolmogorov – Smirnov Statistic | <0.001 | <0.001 | <0.001 | 0.007 | <0.001 |

### 5.5 USING ANOTHER TEST TO VALIDATE TACTT

When reviewing the literature for a test of critical thinking to use in this study, it was also determined that finding a valid, reliable instrument with which to validate TACTT was going to be problematic. Had it been less expensive to use on a large cohort of subject, the WGCTA would have been ideal for this purpose. However, given that many medical students had sat the Undergraduate Medical and Health Sciences Admission Test (UMAT), an instrument that was reported to be valid to measure some elements of critical thinking, this was the best available test with which to validate TACTT (Australian Council for Educational Research, 2003).

The UMAT was developed by the independent Australian Council for Educational Research (ACER) as a tool for selection testing of applicants for Australian Bachelor degrees in medicine and health sciences (ACER, 2003). The first section of the UMAT contains questions that assess the ability "to comprehend, draw logical conclusions, reach solutions by identifying relevant facts, evaluate information, pinpoint additional or missing information, and generate and test plausible hypotheses" (ACER, 2003, p.4). The first section of the UMAT contains 44 multiple choice questions based on a text or information presented graphically. Candidates are allowed 65 minutes to complete this section of the UMAT.

Many of the skills tested in the first section of the UMAT are similar to those being measured with TACTT. Table 12 illustrates how the critical thinking skills tested by the UMAT correspond to those tested in TACTT (the cognitive skills outlined by The American Philosophical Association Delphi Research Report as those incorporated in critical thinking (Facione, 1990)).

Table 12: Critical Thinking: Skills tested by the UMAT and TACTT

| **Skills of Critical Thinking Tested in the UMAT** | **Skills of Critical Thinking Tested in TACTT** |
|---|---|
| Identifying facts<br>Drawing conclusions | Interpretation |
| Comprehending information | Analysis |
| Evaluating information | Evaluation |
| Pinpointing additional information | Inference |

In order to compare a new measure of an entity (e.g. TACTT) with an existing instrument (e.g. the UMAT), an analysis of the relationship is made using correlation coefficients. Correlation coefficients indicate whether the two methods are significantly related. However, it would be unlikely that two tests designed to assess the same attribute (such as TACTT and the UMAT for critical thinking) were unrelated. The question of agreement between two tests is not answered only by a test of significance. High correlations can be found between data which seem to be in poor agreement (Bland and Altman, 1986). Thus when the true value of an entity (e.g. critical thinking) remains unknown, comparing two methods of measuring this entity where neither is an exact measurement involves assessing instead the degree of agreement (Bland and Altman, 1986). Therefore, the relationship of TACTT with the UMAT was compared by using a Bland Altman analysis which is a technique based on graphical methods and calculations (Bland and Altman, 1986).

The differences between TACTT and the UMAT percentage scores were not plotted against either set of scores separately because the difference would have been related to each, a known statistical artefact (Bland and Altman, 1986). The difference (on the y axis) is therefore plotted against the students' mean scores for critical thinking as measured by TACTT and the UMAT (x = (UMAT+TACTT)/2). The closer the agreement between the two instruments, the closer the data points will be clustered around the line y = x. For this cohort (*N* = 80), the plot demonstrated that there was a lack of agreement (no obvious relationship) between these two entities (Figure 4).

However, even though Figure 4 demonstrates a lack of agreement between the two measures of critical thinking, it may still have been possible to use UMAT and TACTT total percentage scores of critical thinking interchangeably, provided the limits of agreement (see below) were not academically important. The limits of agreement are defined as:

Limits of agreement = mean difference +/– (2 x standard deviation of the differences)

The limits of agreement of students' critical thinking scores as measured by TACTT in February 2004 and their UMAT scores were:

Limit of agreement = -1.97+(2 x 17.94) = 33.91   Limit of agreement = -1.97 - (2 x 17.94) = -37.85

These limits of agreement were academically important. Students' percentage scores on TACTT could have been 33.91 more or 37.85 less than their percentage scores for critical thinking ability on the UMAT, which means that the two measures could not be used interchangeably. However, the UMAT itself has not been validated as a measure of critical thinking per se. Thus the validity of TACTT is only questionable. TACTT may be a valid measure of critical thinking, but this is difficult to ascertain without having the ability to compare it with another valid and reliable standard of critical thinking.

## 5.6 CHAPTER SUMMARY

In response to the research question "How can students' critical thinking ability be measured?", this chapter has described the design and development of TACTT. The content of this critical thinking instrument was validated by peer review. TACTT did not show internal consistency when tested on first year medical and science students. A Bland-Altman analysis comparing TACTT with the UMAT demonstrated a limited agreement between these two measures of critical thinking ability. Thus the reliability and validity of TACTT is limited.

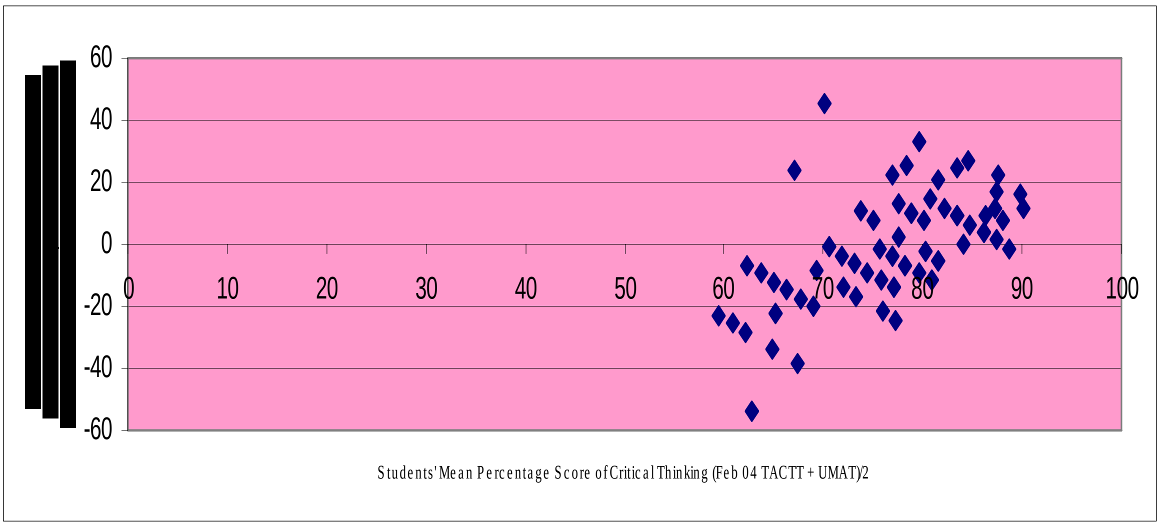



Figure 4: Comparison of TACTT with UMAT: Bland-Altmann Plot

# CHAPTER SIX - THE CASE STUDIES

## 6.1 THE CASE STUDY SELECTION PROCESS

Case studies were used to gain further insight into how student clinical reasoning ability developed over time and the factors that impacted on this ability. Case study selection was a two-step process. As shown in Table 13, initially students were categorized into groups A to E according to their approach to learning and their critical thinking ability (as determined by their R-SPQ-2F category (see section 3.4.1.4 for how the categories were determined) and their total TACTT percentage score, respectively). There were very few students with a surface approach to learning ($N$ = 2), so this student group was not matrixed further by TACTT scores. The TACTT score was used to categorize students into groups despite the instrument's lack of internal consistency because it was the best available measure of critical thinking ability. The cut off point of 76% was used for categorizing students as this was the mean score for critical thinking of the 2004 first year medical students. Using SPSS, students were randomly selected from each matrixed group A to E and invited via email to participate in a taped interview lasting up to one hour. If a student did not wish to be interviewed, the researcher proceeded to invite the next student on the list randomly generated for each category by SPSS. This ensured that students with a broad range of approaches to learning and critical thinking abilities were included in the interview cohort.

Table 13: Student Groups Based on Critical Thinking Ability and Approach to Learning

| **R-SPQ-2F Approach to Learning Category (February 2004)** | **TACTT Critical Thinking Percentage Score (February 2004)** | **Matrixed Group Identifier** |
|---|---|---|
| Deep | ≥76% | A |
| Deep | <76% | B |
| Ill-defined | ≥76% | C |
| Ill-defined | <76% | D |
| Surface | Any Score | E |

Following validation and testing of TACRR as an instrument to measure clinical reasoning in medical students (Chapter Four), it was used to analyse the examination papers (Cases 1 - 7, see Appendix J – M) of students in 2004 and 2005 who had consented to participate in this research.

All students were given an information sheet (Appendix A), and those who participated signed a form (Appendix A), stating that they consented for their examination papers to be used in this way. Once clinical reasoning ability data for students was generated in the form of TACRR scores for case analyses 1 and 2, first year students were further categorised into the matrixed groups according to Table 14 (for information on the case analysis scenarios see Appendices J - P). These categorisations were based on the identification of first year students who demonstrated potentially significant changes in their clinical reasoning ability from Case 1 (completed in the middle of the year) to Case 2 (completed at the end of the year). For example, Group F changed from being weak at clinical reasoning in the middle of the year to having an acceptable clinical reasoning ability the end of the year for first year students. Able to reason extremely well in the middle of the year, Group I changed to demonstrating only borderline clinical reasoning ability by the end of the year. It may be that the content specificity of the questions in the mid and end of year examinations contributed to students' clinical reasoning performance changing over this period of time. However, by purposefully randomly selecting students from the matrixed groups F - J, the potential for their interviews to be information-rich about other factors affecting clinical reasoning development was maximised.

Table 14: Student Groups According to TACRR Analyses of their 2004 Examination Papers

| **TACRR Score Change in 2004** | **Case 1 TACRR Score** | **Case 2 TACRR Score** | **Matrixed Group Identifier** |
|---|---|---|---|
| Increase | <46% | >55% | F |
| No Change | 46-74% | 46-74% | G |
| Slight Decrease | >75% | 55-74% | H |
| Large Decrease | >75% | 46-54% | I |
| Not in Above Categories | Variable | Variable | J |

The TACRR score cut offs used to group students as shown in Table 14 were based on guidelines used for marking in the program, i.e. less than 46% was a “fail”, 46 to 54% was “borderline”, 55 to 74% was a “pass” and greater than 75% was “excellent”. Additional students purposefully randomly selected from categories F to J were interviewed in order to explore the hypothesis that factors affecting clinical reasoning development varied between students with different levels of clinical reasoning ability. In order to gain some insight into the longitudinal development of individual students’ clinical reasoning, a year after the initial interview (see Appendix H for questions), follow-up interviews (see Appendix I for questions) were conducted with purposefully randomly selected students from matrixed groups F to J who were in the initial interviewed cohort. These students of differing levels of clinical reasoning ability became the case studies for this research. Follow up interviews were conducted with eight students before the point of redundancy was reached, and will be described in Chapter Seven.

## 6.2 THE CASE STUDY DATA COLLECTION METHODS

Four different sources were used to provide data for the student case studies, including cases 1 – 4, PBL Journals, PBL Tutor Reports and student interviews. These sources are summarized in Table 15.

Table 15 - Sources for the Case Studies

| **Source for Case Study** | **Details about Analysing the Source** |
|---|---|
| Cases 1 -4 | This is an examination question that models the clinical reasoning process used in PBL. These questions have been labeled Cases 1 – 4 (see Section 6.1.0, Section 7.3.0 and Appendices J - P) and students’ case analyses were scored using TACRR. |
| PBL Journal | Students completed a reflective journal on the third case they analysed in their PBL class in first year medicine. |
| PBL Tutor Report | PBL tutors report four times a year on students’ knowledge base, reasoning development and PBL process skills. Eight reports per student were available for analysis. |
| Student Interview | Up to three semi-structured, open-ended interviews were conducted with each case study student over first and second year medicine. |

### 6.2.1 Cases 1 - 4

During first and second year medicine, the students complete four case analyses as part of their examinations. Cases focus specifically on the clinical reasoning process modeled in the PBL tutorials. These case analyses have a similar structure and are based on the prior learning students have completed in the medical program. These cases are summarised in Table 16. For the full examination lay-out and example answers see Appendices J – P.

All but Case 1 were part of students' summative assessment. Case 1 was formative only, as this was part of the program's Assessment Policy. The clinical scenario students had to analyse for Case 1 and the questions they were required to answer are provided in Figure 1 (see Appendix J for the actual layout of the examination). Cases 2, 3 and 4 follow this same format and are included in Appendices K, L and M, respectively. Typical answers for the examination questions in Figure 1 are provided in Figure 5.

In some of the examination cases (Table 16), the students were given a diagnosis with the case scenario. In PBL tutorials, some students concentrate on problem solving (i.e. arriving at a diagnosis regardless of method) rather than developing their reasoning skills through problem based learning. In order to highlight the importance of learning knowledge and using it to reason through problems, giving the students the diagnosis to the case forces them to make more mechanistic hypotheses and demonstrate their reasoning skills.

Table 16 - Summary of Cases 1 to 4

| Year of Medical School | Case Number | Overview of Case | Was the Diagnosis Given to Students? | Number of Cases Completed in PBL Tutorials Prior to this Assessment |
|---|---|---|---|---|
| 1 | 1 | Inflammatory Bowel Disease | No | 6 |
| 1 | 2 | Cardiogenic Shock from Myocardial Infarction | Yes | 15 |
| 2 | 3 | Rheumatoid Arthritis | Yes | 24 |
| 2 | 4 | Nephrotic Syndrome | No | 33 |

Dan Bush is a 20-year old student at University of South Australia. He presents to his local doctor, during his end of year examinations, complaining of diarrhoea for the last 3 weeks. He says he has been passing 6-7 small semi-fluid motions each day since the attack began. The motions are normal in colour but contain bright blood and mucus. He gets bouts of abdominal pain just before he has to have a bowel action. This pain is located in the lower abdomen, more on the left side than the right. It tends to come on shortly before he has to have his bowels open and he has also experienced discomfort in his rectum at this time, along with some urgency to pass a motion once the pain occurs. The pain is relieved, for the time being, by having a bowel action. His appetite has been only fair during this time, and he "has not been feeling 100%". He has not been nauseated and has not vomited. He has not had a temperature, but from time to time has been "feeling a bit hot and sweaty", mainly when he gets the pain. He acknowledges that he is "pretty worried" about his end of year examinations, which are about to begin. His health through the year has been good and he played football "in the seconds". He has not been outside Adelaide during the year. He has no previous serious illness. On questioning he recalls that he had a similar but less severe attack of abdominal pain and diarrhoea, during the matriculation examinations, but that attack was not so severe as this and he did not notice any blood or mucus at that time. He saw his local doctor and recalls that he had a rectal examination, which was both uncomfortable and painful at that time. The attack lasted only for 2 weeks and settled down quickly with some anti-diarrhoeal medicine, which his doctor prescribed. No specific diagnosis was made at that time and no further investigations were undertaken. He also had loose motions for a couple of days before the exams in the mid-year. He is worried about the effect the illness is having on his exam preparation.

Analyse the data you are given and prepare a short LIST (3-5) of hypotheses. Provide evidence from the data for each hypothesis.

For EACH hypothesis, outline briefly the important mechanism(s) involved in producing the clinical features you chose in part 1.

For each hypothesis/mechanism indicate the learning issues you consider will prepare you and be most helpful to you for answering more detailed questions about the patient and for explaining the mechanisms responsible for his abnormal clinical features. Indicate (with an *) those learning issues which you consider you already have sufficient prior knowledge.

Figure 1 - Case 1 Examination Paper

**Hypotheses**

I think Dan has a 3 week history of diarrhoea, blood and mucus, abdominal pain relieved by passing stool, urgency, a lack of appetite and a history of an episode of 2 weeks of diarrhoea previously due to ulcerative colitis that has been triggered by examination stress (usually occurs in people aged 20-25 years)

I think Dan has a 3 week history of diarrhoea, abdominal pain relieved by passing stool, a lack of appetite and a history of 2 weeks of diarrhoea previously due to Crohn's disease that has been triggered by examination stress (usually occurs in people aged 20-30 years)

It is less likely that Dan has diarrhoea due to a gastrointestinal infection as he has not been travelling, there is no history of food poisoning or others around him being unwell, and this diarrhoea has lasted 3 weeks as well as him having a previous episode. There is also no history of fever, nausea or vomiting.

I think Dan has abdominal pain due to the distension of the colon

I think Dan has blood and mucous in his stools due to inflammation of the colon

**Mechanism**

In genetically susceptible individuals such as Dan, an exaggerated immune response to gut flora is triggered (perhaps by examination stress). This response causes inflammation of the colon mucosa, making it friable and thus mucosal blood vessels bleed and mucus from goblet cells get into the stool. The systemic manifestation of the inflammation may be causing Dan to not feel 100%. In Crohn's Disease this gut inflammation is transmural, discontinuous and can be granulomateous. In Ulcerative Colitis, inflammation is always distal and involves the rectum, and it is more likely to cause blood in the stool and urgency. This makes Ulcerative Colitis a more likely diagnosis in Dan's case. As the inflammation also destroys gut villi and the surface area for absorption of fluid decreases, the stools become more watery and diarrhoea ensues. With increased faeces distending the colon, the muscle layers are stretched, stimulating nerve fibres and thus causing abdominal pain. When stools are passed the distension is relieved and the pain ceases.

**Learning Issues**

What is the mechanism of lower abdominal pain and how can it be relieved by defecation?*
How are watery stools formed and what can cause this?*
What commonly causes blood and mucous in the stools of a 20 year old man?
What causes urgency to defecate?
What are the mechanisms for the systemic manifestations of inflammatory bowel disease?

Figure 5 - An Example Answer for Examination Questions for Case 1

### 6.2.2 Open-Ended, Semi-Structured Interviews

Over a two-year period, interviews with students were completed in order to gain insight into what factors affected students' clinical reasoning development and critical thinking ability, knowledge and approaches to learning might also have affected this process. Questions for the student interview were identified by the researcher and reviewed by medical educators (Appendix H). Interview questions were concrete and open ended to give students the best opportunity to understand the questions being asked and be able to elaborate on their answers. Using the styles of questions suggested by Patton (1980) in order to gain different types of information from respondents, the interviews explored students' thinking, learning and reasoning backgrounds, what students knew and felt about their knowledge, critical thinking, approaches to learning and clinical reasoning, and how students actually thought, learnt and reasoned. In accordance with the four major categories of questions available to interviewers, questions of a hypothetical, devil's advocate, ideal position and interpretive nature were used (Strauss, Schatzman, Bucher and Sabshin, 1981).

The selection process for interviewing students is outlined in section 6.1. All students were informed that they may be selected for interview in the Information Sheet when they consented to be part of the study (Appendix A). However, students were also made aware that they could withdraw from the study at any time. All of the interviews were conducted at a mutually convenient time and place and then transcribed and de-identified. The interview tapes were coded so that the transcriber did not know the identities of the students involved. All students interviewed were given a copy of their own interview transcript and allowed to amend it before approving it for analysis. Any amendments suggested by the student involved were made to the transcripts before they were analysed.

After reviewing the results of the initial interviews and quantitative data from TACTT, the R-SPQ-2F and TACRR, further interview questions were identified for the follow-up interviews conducted with case study students. These questions were more focussed on eliciting other factors that may affect the development of clinical reasoning (see Appendix I). Given that there was little correlation between students' TACTT and R-SPQ-2F scores and their TACRR scores (see results reported in sections 7.3.3.1 and 7.3.5.1), it was concluded that questions that were open-ended and had a larger focus on clinical reasoning development would yield more information-rich interviews than further questions about critical thinking, knowledge and approaches to learning.

## 6.3 THE ANALYSIS OF THE CASE STUDY DATA

The data in the case studies were analysed as they were collected, not just after all of the information had been gathered. For example, questions for follow up interviews (Appendix I) were established only after reviewing students' TACTT, TACRR and R-SPQ-2F scores. This timing of analysis and the impact it has on a study is one of the factors that distinguishes a qualitative from a quantitative research method: "data collection and analysis is a *simultaneous* activity in qualitative research" (Merriam, 1998).

> *Unlike experimental designs in which validity and reliability are accounted for before the investigation, rigor in a qualitative research derives from the researcher's presence, the nature of the interaction between researcher and participants, the triangulation of data, the interpretation of perceptions and rich, thick description.*
> (Merriam, 1998, p.151).

During the student interviews, inductive, within-case analysis was done by the researcher. Recurring themes or distinctive aspects about each student's responses were noted in a journal. These notes were reviewed and expanded as the researcher listened to the interviews and read the transcripts. Through content analysis, the information in the interviews was then categorised according to principles of convergence - looking for recurring regularities in the data (Patton, 2002). The categorisation process was influenced by (1) the semi-structured, open-ended interview questions, (2) the hypothesis that critical thinking, knowledge and approaches to learning influenced clinical reasoning development, (3) patterns identified during the actual interviews and the initial review of the interviews and (4) additional categories of information that did not fit into the existing framework. Categories were scrutinised for internal and external homogeneity. "The first criterion concerns the extent to which the data that belong in a certain category hold together… the second criterion concerns the extent to which differences among categories are bold and clear" (Patton, 2002, p.465). The researcher then used deductive analysis when triangulating sources for the cases and reviewing all written interview transcripts, PBL journals and PBL tutor reports, looking for information that expounded upon that gathered in the categories in the existing framework. Deductive analysis was also used for cross-case analysis between different student case studies (Merriam, 1998). Throughout this process, the case study sources were analysed for divergence i.e. the researcher sought to expand the categories.

> *This is done by the processes of extension (building on items of information already known), bridging (making connections among different items), and surfacing (proposing new information that ought to fit and then verifying its existence). The analyst brings closure to the process when sources have been exhausted, when sets of categories have been saturated so that new sources lead to redundancy, when clear regularities have emerged that feel integrated, and when analysis begins to overextend beyond the boundaries of the issues and concerns guiding the analysis. Divergence also includes careful and thoughtful examination of data that doesn't seem to fit.*
> (Patton, 2002, p.466).

Within-case and cross-case analysis made it possible to identify and explore five themes relating to clinical reasoning development:

- reflecting upon the modelling of clinical reasoning,
- practising clinical reasoning,
- critical thinking about clinical reasoning,
- acquiring knowledge for clinical reasoning and
- the approach to learning for clinical reasoning.

These themes are discussed within the context of the case studies here and more extensively in Chapter Seven.

## 6.4 THE CASE STUDY PARTICIPANTS

Fifty-three students were interviewed as part of this study. Eight of these students were purposefully selected as case studies (see section 6.1 for details of the selection process) and five of these case studies are reported in detail as part of this thesis. Information from the remaining three case studies and other interviews is included in further discussion in Chapter Seven. The case study students have been given code names in order that their identities remain confidential. However, the students' gender, total percentage TACRR scores for the case analyses, their critical thinking ability (percentage TACTT score), measure of knowledge scores and approach to learning categories according to the R-SPQ-2F (see section 3.4.1.3 for the categorisation process) are given in Table 17.

From Table 17 it is evident that in general, the case study students demonstrated a broad range of TACRR scores for each individual case analysis, a broad range of changes in TACTT scores and a broad range of knowledge scores over the two year period. Alison and Chris generally had the highest knowledge scores, although Hannah also performed well on the examinations A, B and C. Chris and Brianna were the only students to change their approach to learning. Overall, students' TACTT scores tended to remain stable over their first year of Medicine. A detailed overview of the case study students' performance on each of the case analyses 1 to 4 is provided in Table 18.

### 6.4.1 Alison

Alison was classified as a deep learner and good critical thinker (Table 17) and she developed the ability to reason clinically early in the medical course, scoring 78% for the Case 1 Analysis. As illustrated in the following excerpt from Alison's Case 1 Analysis, she generated appropriate hypotheses and supported these hypotheses with relevant clinical information. This demonstrates the critical thinking ability of explanation:

> a. *I think that he has ulcerative colitis in colon, rectosigmoid colon region due to presence of (exposed surface) mucous/blood in stools, pain in a lower area before bowel action and relieved by defecation (sensitive areas, previous similar attacks (gets worse/better), no temp, vomiting (unlikely infection)*
> b. *I think he has bacterial/viral gastroenteritis invasion of mucosa that is aggravated in stressful situations or antibiotics (anti-diarrhoeal medication) - in colon, rectosigmoid region (pain) but not fever-causing*
> c. *I think he has diverticulitis due to 3 week duration, blood/mucous from straining, ↑ need to defecate, urgency + pain relieved by defecation*
>
> (Alison, Case 1 Hypotheses, June 21, 2004)

[In her case analyses, Alison, similar to other students, used the upright arrow (↑) to indicate "increase" and the downwards arrow (↓) to indicate "decrease". The sideways arrow (→) is often used by students to mean "leads to" or "causes".] Alison's first two hypotheses were well explained by the clinical information she provided, and her third hypothesis, although less likely, was also supported with evidence from the case.

Table 17 – Summary of Case Study Data

| Student | Sex | | TACRR Total Percentage Score | | | | TACTT % Score 2004 | | R-SPQ-2F Approach to Learning 2004 | | Measure of Knowledge Percentage Score | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Semester 1, 2004 | | | Semester 2, 2004 | | | Semester 1, 2005 | | | | Semester 2, 2005 | | | |
| | Female | Male | Case 1 | Case 2 | Case 3 | Case 4 | Feb | Oct | Feb | Oct | Exam A | Exam B | TACRR | Exam A | Exam B | TACRR | Exam A | Exam B | Exam C | TACRR | Exam A | Exam B | Exam C | TACRR |
| Alison | X | | 78 | 38 | 72 | 73 | 82 | 79 | Deep | Deep | 59 | 59 | 70 | 75 | 62 | 50 | 74 | 60 | 71 | 70 | 65 | 50 | 60 | 70 |
| Chris | | X | 46 | 80 | 74 | 74 | 89 | 82 | Void | Deep | 68 | 70 | 40 | 84 | 78 | 80 | 77 | 81 | 84 | 80 | 71 | 74 | 74 | 70 |
| Brianna | X | | 55 | 78 | 67 | 55 | 74 | 79 | Deep | Void | 47 | 40 | 50 | 57 | 49 | 80 | 60 | 40 | 62 | 70 | 55 | 32 | 58 | 50 |
| Frank | | X | 40 | 74 | 57 | 46 | 76 | 76 | Deep | Deep | 63 | 48 | 40 | 71 | 61 | 80 | 76 | 59 | 73 | 50 | 59 | 58 | 72 | 50 |
| Hannah | X | | 85 | 52 | 44 | 50 | 84 | 84 | Deep | Deep | 64 | 53 | 90 | 77 | 65 | 60 | 67 | 63 | 70 | 30 | 68 | 63 | 79 | 50 |
| Class Average | | | 55 | 54 | 58 | 54 | 76 | 77 | | | 55 | 48 | 52 | 66 | 59 | 56 | 66 | 55 | 67 | 57 | 62 | 56 | 60 | 50 |
| Standard Deviation | | | 13 | 16 | 13 | 13 | 9 | 10 | | | 8 | 12 | 14 | 7 | 8 | 17 | 10 | 10 | 9 | 16 | 7 | 10 | 10 | 12 |

Table 18 - Case Study Students' TACRR Scores for Examination Cases 1 to 4

| Student | Case Number | Individual TACRR Criteria and Total TACRR Scores | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Total** |
| | 1 | 10 | 9 | 8 | 8 | 8 | 8 | 8 | 4 | 7 | 8 | 78 |
| Alison | 2 | 8 | 3 | 4 | 0 | 3 | 3 | 6 | 2 | 5 | 4 | 38 |
| | 3 | 8 | 8 | 8 | 8 | 7 | 7 | 8 | 4 | 7 | 8 | 72 |
| | 4 | 10 | 8 | 7 | 8 | 6 | 6 | 7 | 7 | 7 | 7 | 73 |
| | 1 | 6 | 6 | 3 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 46 |
| Chris | 2 | 10 | 9 | 9 | 8 | 7 | 7 | 8 | 6 | 8 | 8 | 80 |
| | 3 | 8 | 7 | 7 | 8 | 8 | 7 | 8 | 5 | 8 | 8 | 74 |
| | 4 | 8 | 8 | 6 | 6 | 7 | 8 | 8 | 7 | 7 | 8 | 74 |
| | 1 | 6 | 6 | 7 | 6 | 5 | 4 | 5 | 7 | 5 | 5 | 55 |
| Brianna | 2 | 8 | 8 | 9 | 6 | 9 | 8 | 10 | 4 | 8 | 8 | 78 |
| | 3 | 8 | 7 | 8 | 6 | 6 | 6 | 8 | 5 | 7 | 6 | 67 |
| | 4 | 8 | 7 | 4 | 6 | 4 | 5 | 5 | 5 | 5 | 6 | 55 |
| | 1 | 6 | 4 | 4 | 2 | 3 | 4 | 5 | 4 | 4 | 4 | 40 |
| Frank | 2 | 8 | 8 | 9 | 4 | 8 | 8 | 7 | 6 | 8 | 8 | 74 |
| | 3 | 8 | 4 | 3 | 6 | 5 | 7 | 7 | 5 | 5 | 6 | 57 |
| | 4 | 6 | 5 | 3 | 4 | 4 | 4 | 6 | 3 | 5 | 6 | 46 |
| | 1 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 8 | 9 | 9 | 85 |
| Hannah | 2 | 6 | 3 | 3 | 6 | 5 | 6 | 8 | 3 | 6 | 6 | 52 |
| | 3 | 6 | 6 | 2 | 6 | 3 | 5 | 6 | 2 | 3 | 4 | 44 |
| | 4 | 4 | 5 | 4 | 6 | 5 | 5 | 6 | 3 | 5 | 6 | 50 |

According to Alison's scores for Examination A (biomedical knowledge tested in the form of multiple choice and short answer questions) and Examination B (biomedical questions based on human prosections or histological slides), her knowledge level was not high at the time she did the Case 1 Analysis (Table 17). However, Alison's tutors considered that she was "developing a very good knowledge base" and that she "managed to utilize her knowledge well" in PBL (Alison, PBL Tutor Report, April, 2004). Alison's ability to use what she had learnt to reason through cases was supported by her TACRR knowledge score of 7/10 for her Case 1 Analysis. It appears that Alison could retrieve and demonstrate a larger knowledge base when reasoning through a case than when asked to retrieve knowledge independently of a case, as shown in the following mechanisms.

> *ulcerative colitis → epithelial cells sloughed away → exposure of blood vessels/nerves to lumen → (straining as more sensitive to presence of faeces → [↑ mucous production by other cells in attempt to ↑ lubrication and quickly get rid of faeces] + [↑ peristaltic movements to remove faeces, ↓ time for absorption of fluid → diarrhoea fluid and ↑ urgency to defecate]), nerves easily stimulated to cause pain (unmyelinated fibres) synapse with spinal cord nerves supplying the region of L colon (embryological development) and inflammation, chemicals released stimulate nerves → ↑ permeability of capillary membranes → ↑ fluid, blood*
>
> *stress and/or anti-diarrhoeal medication → competing bacterial flora → use pilli to adhere to epithelial cells (invasion) → invade epithelial cells,inflammation, ↑ goblet secretion → ↑ mucous production, ↑ production CAMP → inhibits Na+ absorption → Cl- and H2O leave → secretory diarrhoea*
>
> *[UNLIKELY] diverticulosis: weak muscle foci in rectosigmoid region and ↑ straining (stress about exams?) → muscle outpouchings → ulcerations → blood and mucous inflammation (diverticulitis) → resident macrophages and neutrophils accumulate, releasing chemicals prostaglandins → stimulate C-nociceptors (pain)*
> *↓ pressure of faeces causes distension → stimulates C-nociceptors, stimulates peristaltic movements → ↑ desire/urgency to defecate → ↓ pressure from distension → less pressure on nociceptors reduces pain*
> (Alison, Case 1 Mechanisms, June 21, 2004)

Most of the mechanisms Alison detailed for Case 1 were correct and logical, as demonstrated in the above example, so she achieved scores of 8/10 for these components of the Case 1 Analysis. In general, Alison's mechanisms highlight the correct pathophysiology behind the patient's symptoms. Her arguments flow logically and Alison also makes the distinction that diverticulosis is a much less likely reason for the patient's symptoms than her other two hypotheses.

Alison's early development of clinical reasoning may have been helped by her critical thinking ability. Alison's ability to interpret information, make inferences and self-regulate was noticed early in year one medicine by her PBL tutor who identified that she could "identify important data… and establish their potential significance", that she was "very questioning in her approach… as to why… information is important and how it fits into the case" and that she "managed to identify areas… which she feels they are doing well along with areas that could be improved", respectively (Alison, PBL Tutor Report 1, April, 2004).

Alison identified early in the course that receiving new information about a case meant she would have to use critical thinking skills of analysis, evaluation and inference to reprioritise her hypotheses. In PBL she had to "think 'What are all the possibilities?'… That whole differential diagnosis thing each time we get new information,… changing the order – 'What's more likely?', 'Less likely?'" (Alison, Interview 1, May 19, 2004). Alison's second PBL tutor highlights her skills of inference, analysis, evaluation, stating that she had "the ability to think laterally, meaning that she often comes up with alternative hypotheses that may have otherwise gone without explanation… she… [would] further develop and/or refine hypotheses, as well as propose alternative… ones" (Alison, PBL Tutor Report 2, June 2004). By using these critical thinking skills and practising clinical reasoning during PBL tutorials, Alison was able to effectively analyse Case 1.

However, Alison found it difficult to analyse Case 2 where she was given a diagnosis. Although the ECG confirmed the Case 2 patient's diagnosis of a myocardial infarction, Alison proceeded to list other diagnostic hypotheses for the patient's symptoms, rather than mechanistic hypotheses for the myocardial infarction. Alison also did not explain the patient's symptoms of heart failure, but instead detailed hypotheses about gastrointestinal causes for the patient's problems, although there was no clinical information to support these diagnoses.

> *I think the patient's central crushing pain due to* ***myocardial infarction from CAD leading to cardiogenic shock*** *brought on by emotional exertion (horse races)*

*Support:* ***CAD:*** *male, high amts of fatty foods, butcher → ↑ chance of atherosclerosis → PVD → ↓ distal pulses* ***MI:*** *horse races precipitated by exertion, central chest pain, referred pain to L arm/jaw, ECG confirmation, murmur*
*Detract:*
*nothing specifically, except that other causes of MI also likely (other than CAD) e.g. pain in epigastrium*

*I think the patient's tender epigastrium and vomiting due to* ***GORD*** *stimulated by food*

*Support:****GORD:*** *spicy, fatty food from butcher → ↑ acidity, vomiting, reflux after eating, tender epigastrium (vague localisation of pain), taking meds for reflux*
*Detract:doesn't explain MI/central chest pain, lung crepitations, ↑JVP, paleness, cyanosis, sweating etc.*

*I think the patient's sweating/cyanosis/lighthead is due to* ***hypovolemic shock secondary to perforated peptic ulcer***

*Support: S&S of* ***shock*** *ie, sweating, peripheral cyanosis, pale, weak distal peripheral pulses.* ***Perforated Peptic Ulcer:*** *failing heart – MI (ECG), central chest pain etc, lung crepitations*
*Detract: NO BLOOD – important -ve*

*I think the patient's sweating/cyanosis/lighthead and central chest pain is due to MI (from emotional exertion (horse races)) secondary to anemia from chronic blood loss due to peptic ulcer*

*Support:* ***Chronic peptic ulcer:*** *taking reflux meds for 2 yrs, tender epigastrium, vomiting.* ***MI:*** *ECG confirmation, central chest pain, referred pain L arm/jaw, horse races precipitation*
*Detrac:nothing specifically, no direct evidence of anaemia, no blood in vomitus but previous blood loss could still lead to anaemia*
(Alison, Case 2 Hypotheses, November 8, 2004)

Alison's knowledge level and overall approach to Case 2 was less erudite than her approach to Case 1. Alison's Case 2 mechanisms (see below) highlight an inability to apply relevant knowledge. Although some of Alison's reasoning was correct, there was no explanation of how atherosclerosis occurs or how coronary artery disease (CAD) leads to heart failure. Alison's hypothesised gastrointestinal reasons for the patient's condition are difficult to justify in the absence of gastrointestinal symptoms and therefore her reasoning for these mechanisms was less logical. Alison only achieved 3/10 for the correctness of and logic in her Case 2 mechanisms, compared with 8/10 for her Case 1 mechanisms.

> *Butcher, fatty foods, 49yo, male = risk factors for atherosclerosis → ↑ LDLs → in coronary arteries (CAD) → see below to heart failure*
>
> *Weak lower oesophageal sphincter and fatty/spicy foods → ↑ acid → stimulates reflux → oesophagus irritated (nociceptors) → pain*
>
> *H pylori → peptic ulcer → acute blood loss (shock) → ↓ perfusion of lungs → ↑ work of breathing → dyspnoea*
>
> *H pylori → chronic peptic ulcer → chronic upper GI bleeding → ↓ rbc's in blood → ↓O2 carrying capacity of blood (anaemia) → ↓ cardiac reserve → see below to heart failure*
>
> *↓ blood volume → ↓viscosity of blood (hyperdynamic circulation)→ ↑ venous return and horse race emotional exertion → ↑ heart rate→ see below to heart failure*
>
> *↓ BP→ baroreceptors in aortic/carotid artery → dyspnoea,↑ venous return and ↑ heart rate → see below to heart failure*
>
> *Heart failure due to ↑ demand but not enough supply → cardiogenic shock → vasoconstriction of systemic arterioles → pallor, backflow of blood pressure in pulmonary vessels → basal crepitations, backflow of blood pressure in systemic vessels → ↑ JVP +3cm*
> (Alison, Case 2 Mechanisms, November 8, 2004)

It is interesting to note that according to Alison's Examination A and B scores, her knowledge level had improved between doing Case 1 and Case 2, and her tutors commented that her "knowledge base is very extensive" and she "had an ability to retain details extremely well" (Alison, PBL Tutor Report, October 2004). However, simply knowing information did not help Alison in the Case 2 Analysis, as she was unable to demonstrate how this knowledge applied to this current situation and she only scored 5/10 for knowledge in TACRR for this case.

The fact that Alison struggled to develop concise learning issues throughout first year medicine may have affected her ability to develop an applicable knowledge base.

> *At the beginning, the learning issues were quite broad. [They were] just a general question; "What is this?" So you'd look at it, [and find it's]… a whole book!.... Sometimes at the end of… a PBL case, if I ask myself,*

*"Exactly what do I need to know?"… I can't exactly answer that question."*
(Alison, Interview 1, May 19, 2004)

Alison's PBL tutor reported that she needed to practice "developing more concise learning issues… rather than ambiguous learning issues that have been difficult to research" (Alison, PBL Tutor Report, April, 2004). The learning issues Alison detailed in her Case 1 and 2 were broad and did not address working out exactly how the patient's symptoms and signs could be explained, and so she only scored 4/10 and 2/10 for these learning issues in her analysis of Case 1 and Case 2, respectively .

*1. What bacteria cause bloody/mucous diarrhoea lasting 3 weeks?*
*2. How may diverticulitis lead to ↑ peristaltic movements?*
*3. What is the pathogenesis of worm infestations (incubation period)?*
(Alison, Case 1 Learning Issues, June 21, 2004)

*1. What else causes epigastric pain/referred pain that affects heart?*
*2. Affect of alcohol on peptic ulcers.*
*3. When does Zollinger-Ellison syndrome present? What precipitates this?*
(Alison, Case 2 Learning Issues, November 8, 2004)

Alison's PBL Tutor Report verifies that was still unable to demonstrate that she could make "specific learning issues… on a consistent basis" at the end of first year medicine (Alison, PBL Tutor Report 3, September 2004).

Alison's poor performance on the case analysis at the end of first year medicine also may have been because she did not utilise her critical thinking skills as much to reason through Case 2. Alison's PBL tutor had noticed that although she could interpret information ("recognise relevant information"), "an attempt to develop hypotheses can sometimes let her thought processes wander to more difficult mechanisms and consequently [she] might miss a more simple solution" (Alison, PBL Tutor Report 4, October 2004).

Providing students with the diagnosis, as was done in Cases 2 and 3, required them to focus on more mechanistic hypotheses. Alison found this difficult to do in Case 2 but by Case 3, Alison had further developed her clinical reasoning. Alison performed well in both Case 3 (72%) and Case 4 (73%). This may be attributed to

Alison's focus on applying what she was learning and using it to reason:, "if I have less time it will be more about just applying less information to the case", whereas with "more time it will be about learning more and then applying how much I have" (Alison, Interview 3, August 17, 2005). Irrespective of the amount of time Alison had to study and develop her understanding, the important aspect was that her constant application of knowledge meant she was able to have a "really good understanding of what [she was] learning" (Alison, Interview 3, August 17, 2005). This was supported by Alison's PBL tutor reports, which stated that she had "good knowledge in most areas" (Alison, PBL Tutor Report 8, October, 2005).

By second year medicine, Alison had also improved her ability to make learning issues. She achieved 7/10 for this demonstrating this skill in her analysis of Case 4, and Alison's PBL tutors reported that she "consistently demonstrated an ability to… develop specific/concise learning issues,… link learning issues to aspects of the case and… identify relevant knowledge required for the problem" (Alison, PBL Tutor Report 8, October 2005). This increase in ability to determine what she needed to learn may have helped Alison to develop an applicable knowledge base that she could then use for clinical reasoning.

Alison scored 8/10 for detailing appropriate hypotheses in Case 3, as her hypotheses aimed to explain the patient's symptoms and signs. However, Alison's mechanisms for these hypotheses (see below) demonstrated some confusion and therefore she only scored 7/10 for their correctness in her Case 3 Analysis, and 7/10 for her level of knowledge. However, these scores are similar to Alison's Case 1 Analysis scores of 8/10 and 7/10 for these sections, respectively.

> *Immune system attacks joints (which it sees as 'foreign') – T-h cells activate B cells to differentiate into Abs → attacks synovial membrane – in a pattern consistent with RA (symmetrical PIPs, MCPs etc) immune complexes found → attract phagocytosis. Also, T-h cells trigger macrophages (via cytokines) to involve inflammatory processes →*
> *↑ swelling d/t ↑ vascular permeability & fluid transudation into ISF +painful d/t swelling compressing nerves & d/t inflammatory mediator release stimulating nociceptors + stiff movement d/t swelling interfering with smooth locomotion around joint region*

> *Previous viral infection → viremia in blood triggered immune response that caused release of various inflammatory mediators leading her to feel tired & run down, ↓ appetite etc. (systemic sxs) & poss. fever. This virus, now gone, possibly caused her body to change its defence against itself (molecular mimicry) since it mimicked body's own tissues*
> (Alison, Case 3 Mechanisms, June 20, 2005).

A review of Alison's PBL Tutor Reports throughout years one and two of medicine show that she consistently demonstrated the clinical reasoning skills of being able to "identify important data points… establish their potential significance… [and] use this information to propose some intelligible hypotheses… around the signs and symptoms being displayed by the patient" (Alison, PBL Tutor Report 1, April 2004). Alison was "logical in her presentation of mechanisms, supporting individual steps in the reasoning process with relevant findings, and asks questions that help to clarify the problem" (Alison, PBL Tutor Report 4, October 2004). Overall, Alison has good clinical reasoning "process skills" and this was confirmed by her achieving 73% for her Case 4 Analysis (Alison, PBL Tutor Report 8, October 2005).

Alison's knowledge base continued to expand throughout the first and second year of medical school. However, Alison commented that it was best if she learnt "the whole big picture and see how it relates [to cases] because otherwise you have all this information that you haven't kind of connected in any way… I think it's really important to relate everything" (Alison, Interview 1, May 19, 2004). Alison elaborated her knowledge as she learnt it, always making sure that it was linked in her mind for easy retrieval. Alison stated that growing a knowledge base for reasoning was achieved by "building on understanding… there's so much knowledge out there it's just impossible at this stage to know – be able to link everything up – but it builds on and on.  Every bit is like fitting into the bigger picture which is good" (Alison, Interview 3, August 17, 2005). This process of learning knowledge that she could then apply helped Alison to reason through cases.

Alison saw clinical reasoning as "very important" as without "reasoning… you can't think… you're not going to be able to help" (Alison, Interview 3, August 17, 2005). Thus Alison practised clinical reasoning in PBL and was noted to be "involved in the process… and in the discussion" (Alison, PBL Tutor Report 8, October, 2005). Alison confirmed that practising led to being more competent, as "you can only get that sort of thing through more experience" (Alison, Interview 3, August 17, 2005). Alison also commented that in order to develop clinical reasoning it was important to "seize every opportunity… learn from your tutor in clinical skills, practise on other students when you have time and if you get the chance to see patients practise on them" (Alison, Interview 3, August 17, 2005).

In summary, Alison had a deep approach to learning and was identified as a critical thinker. The TACRR scores suggest that Alison was competent at clinical reasoning in all but Case 2. This may suggest that due to case specificity, using just one clinical case per test with TACRR does not give a reliable measure of a student's clinical reasoning ability. However, the qualitative research gives further insight how Alison's clinical reasoning developed. Although initially she struggled with reasoning through a case when given the diagnosis (Case 2), Alison improved at this skill (Case 3) after consistently applying her knowledge, using critical thinking skills and practising clinical reasoning regularly. In second year medicine Alison became more proficient at developing useful learning issues. These factors seemed to augment the development of Alison's clinical reasoning ability so by the end of her first two years at Medical School, Alison had developed competence in all the criteria of clinical reasoning.

### 6.4.2 Chris

Chris was categorised as a good critical thinker and changed from having an ill-defined approach to learning to having a deep approach to learning over first year medicine (see Table 17). This change was validated by information gained during the interviews. Chris graduated from high school three years before beginning Medicine. Prior to starting university, Chris was conscripted into the army. At school, Chris' learning was driven by the desire to please his parents and his friends and this learning was very directed.

> *I don't come from Australia… Our education system is more… memory-based I guess, rather than creative thinking, or thinking out of the box… reading, memory work, practice questions, over and over again… rote learning…. I just write down what our teachers say. And because we take a standardised examination… most of the questions are, kind of, repeat questions - they follow the same order. So… our teachers have good experience so they tell us where we should focus on… and from there you*

*just item-memorise it, or try and understand what the textbook's trying to say, or basically just ask your teacher and see what she or he says.*
(Chris, Interview 1, April 27, 2004)

Chris had never really had an assignment where he had to research and where the mark was added to his final grade. He stated that "we do have assignments but they don't really contribute to our final grade. So, we're not really serious on the whole research thing" (Chris, Interview 1, April 27, 2004). Therefore, initially Chris found PBL difficult.

However, Chris recognised early that PBL required integrated research and application of knowledge, not just rote learning. Chris' approach to learning began to change:

*It's more self-directed… It's more research-based,… the PBL stuff that you've really got to read-up. You've got to understand it by yourself…. There's much less memory work, more understanding of concepts... You really have to get out of the mode of trying to memorise things, and try more, like, understand basic concepts. And that's where I find that my previous learning habits of doing mind maps were useful.*
(Chris, Interview 1, April 27, 2004).

Chris' understanding of how to make learning issues also developed markedly over his first year of Medicine. Initially, Chris' learning issues were "as a group… pretty much what [they did not] understand" (Chris, Interview 2, August 26, 2004). However, by the end of first year medicine, Chris had learnt to make his own learning issues and his PBL tutor reported that he was able to "develop concise learning issues… and link learning issues to aspects of a case" (Chris, PBL Tutor Report 4, October 2004). Chris explained that

*in Semester one… you just do every single one of them and try and squeeze every bit of information out of your textbooks and then plan on just getting the learning issues done. But… it's a bit different now… from experience you… try to look at a case in a big picture and after that I do my learning issues, the important ones.*
(Chris, Interview 2, August 26, 2004)

Chris' deeper understanding of how to make effective learning issues was reflected in his TACRR score for the learning issue section of Case 2, as he scored 6/10 for this analysis compared with only 4/10 for Case 1. The learning issues from Chris' Case 1 were not specific and did not seek to provide mechanistic explanations for the patient's presenting symptoms and signs.

> *1. Pathology of large intestine that can lead to pain and diarrhoea*
> *2. Conditions affecting large intestines that commonly affect young people.*
> *3. Body's physiological response to stress.*
> (Chris, Case 1 Learning Issues, June 21, 2004)

Chris continued to develop his ability to define learning issues throughout second year medicine and his PBL tutor noted that he "consistently demonstrated the ability to… develop concise learning issues,… link learning issues to aspects of a case and… identify knowledge required for the problem" (Chris, PBL Tutor Report 8, October 2005). Chris' ability to make learning issues was demonstrated by scoring 7/10 for this section of Case 4. Chris' learning issues were tailored towards understanding how to explain the patient's symptoms and signs, as illustrated below.

> *1. How do kidney problems lead to oedema?*
> *2. How do cardiac problems lead to oedema?*
> (Chris, Case 4 Learning Issues, November 7, 2005)

Chris' ability to define useful learning issues may have helped him to develop knowledge applicable for clinical reasoning, as his knowledge level and ability to reason clinically improved in parallel with the development of this skill.

Chris' change of his approach to learning from being a rote learner (at school), to someone who sought to understand concepts (in Medicine) was also evident in his responses to the Biggs' R-SPQ-2F questionnaire (Table 17). Chris changed from having an ill-defined approach to learning to being categorised as having a deep approach. This change in approach to learning coincided with Chris's vast improvement in reasoning. Chris scored poorly on all criteria in the Case 1 Analysis. Chris explained that although he thought he understood the procedure of clinical reasoning, "under exam conditions, to reproduce all that [was] quite a different thing" (Chris, Interview 2, August 26, 2004). On reflection, Chris believed that the most difficult part of the examination was knowing the significance of data points, as he started panicking and "probably miss[ed] out on some points… which [may have been] very significant" (Chris, Interview 2, August 26, 2004). This was highlighted by Chris only sometimes detailing appropriate hypotheses (scoring 3/10 for this section of his Case 1 Analysis), as illustrated in the following example:

> *Obstruction of the large bowels due to a tumour which has probably ulcerated. Evident by lower abdominal pain, diarrhoea lasting 3 weeks with associated blood and mucus in stools. Pain comes on before defecation and relieved on defecation.*
>
> *Severe inflammation of bowel walls in sigmoid colon causing obstruction. Evident by the perianal pain and in lower abdomen. Pain comes on before defecation and relieved on defecation. Pain has present for 3 weeks*
>
> *Diarrhoea and abdominal pain brought on by stress-related response by the body. Present situation occurs during examinations. Previous attacks less severe during examinations in the past.*
>
> *Varicose veins in rectum which have ulcerated. Evident by the bright blood in stools and pain in perianal region just before defecation and relieved by defecation.*
> (Chris, Case 1 Hypotheses, June 21, 2004)

Chris did not recognise the significance of the cues in the patient's history, and this made almost all of his hypotheses unlikely. The pain was not typical of obstruction, the patient was too young for a tumour to be the most probable diagnosis, and stress alone does not cause bloody diarrhoea. Chris' Case 1 mechanisms provided limited detail and did not explain how the patient's symptoms and signs had come about.

> *Inflammation of entire sigmoid colon wall → colon wall is oedematous and causes obstruction → increase motility and stronger contractions by intestines → results in diarrhoea and pain especially on left side referred to perianal.*
>
> *Stress → ? body responds to stress physiologically → pain in abdomen and diarrhoea*
> (Chris, Case 1 Mechanisms, June 2004)

It was noted by his tutor that Chris' "knowledge base is amongst the best in the PBL group" (Chris, PBL Tutor Report, May, 2004). Chris certainly scored well in Examination A and B (biomedical knowledge tested in the form of multiple choice and short answer questions or by questions based on human prosections or histological slides) at the time of his Case 1 Analysis, but he seemed unable to apply this knowledge to cases and use it to reason, and as a result only scored 4/10 for the knowledge section of the Case 1 TACRR analysis.

Chris' PBL tutor noted in early 2004 that he needed to "ask more questions to help clarify problems", and that although they thought he had good reasoning skills, he would develop his reasoning much more if he thought "out loud… more often" (Chris' PBL Tutor Report, May, 2004). Chris seemed to act on this advice, and change his approach to learning. The fact that in his own learning, Chris tried to "link all the information" he gathered "back to the case" (Chris, PBL Journal, May 6, 2004) and that he liked to "see how things are correlated to each other… [how] bits and pieces form together to make a jigsaw puzzle" meant that Chris integrated and applied his knowledge as he was learning, and at the same time practised his reasoning (Chris, Interview 1, April 27, 2004). Chris preferred this way of learning because "if you can see the whole picture it's easier to absorb so much more information, rather than trying to memorise the separate entities", and this elaboration of knowledge was good for the development of his clinical reasoning. There was marked improvement of Chris' case analysis scores (80%, 74%, 74% for the Cases 2, 3 and 4, respectively). Chris' decision to make hypotheses about "symptoms… and signs", followed by compiling a list of "differential diagnoses and limiting it to the one that's most probable,… giving it priority" meant that Chris also spent most of his time "researching the symptoms presented by the patient and the signs elicited [that would then] yield mechanisms [he] could relate to other diseases without individually reading up on each disease" (Chris, PBL Journal, May 6, 2004).

Having reflected upon his approach to learning and integrating knowledge, Chris' performance on the Case 2 Analysis indicated that he had a much better understanding of the reasoning process. Chris was now able to understand that it was best if his learning was directed to understanding the patient's "symptom or sign", rather than "being diagnosis driven until [he found] an answer" (Chris, Interview 2, August 26, 2004). This approach enabled Chris to increase his medical knowledge and learn for understanding, whilst practising clinical reasoning, and helped him to perform much better in his examinations.

In the second semester of first year medicine, Chris' PBL tutor had noted that he was able consistently to present ideas in a logical, step-wise manner, ask questions to help clarify the problem, and re-evaluate hypotheses in response to new information. Thus Chris' critical thinking skills of interpretation, explanation, analysis and evaluation and his ability to use these for clinical reasoning had improved (Chris' PBL Tutor report, October, 2004). This development of clinical reasoning is evident in Chris' approach to Case 2. Almost all of his hypotheses were appropriate for the patient's presentation and explained the patient's symptoms and signs in detail:

> *I think he has a myocardial infarct secondary to acute plaque event.*
> *Supported by sudden onset of pain, cardiac type pain which is crushing, severe and radiates to left arm and jaw. ECG also shows evidence of myocardial infarct anterolaterally. Risk factors for CAD – overweight and male.*
>
> *I think his sweating, pallor, tachycardia, tachypnoea due to cardiogenic shock secondary to myocardial infarct.*
> *Patient exhibits symptoms and signs of shock including sweating, vomiting x 2, light-headedness, peripheral cyanosis, pallor, tachycardia and tachypnoea possibly due to increased sympathetic stimulation as a compensatory measure and lack of perfusion to brain and peripheries. The fact that ECG shows myocardial infarct increases possibility of cardiogenic shock. However, he does not feel thirsty which is negative for shock.*
>
> *I think he has breathing difficulties and crepitations due to pulmonary congestion secondary to left ventricular failure and leading to right ventricular failure.*
> *Crepitations probably due to back pressure from a left ventricular failure which could be caused by myocardial infarct. The pressure could have also been transferred retrograde to the right heart resulting in raised JVP. Possible oedema too as distal pulses hard to feel. Indicative of a possible right ventricular failure. No signs of pitting oedema and time course too acute for onset of right ventricular failure.*
>
> *I think his irregular heart beat and premature ventricular contraction is due to damage cardiac conduction probably as complication of myocardial infarct.*
> *Irregular heart beat and premature ventricular contraction due to damage nerve fibres of the heart leading to abnormal/arrhythmic conductions. This is a possible complications of myocardial infarct which has affected the heart fibres. However, patient has normal sinus rhythm which is a negative.*
> (Chris, Case 3 Hypotheses, November 8, 2004)

This change in Chris' hypothesising ability may have been related to a concerted effort to practise explaining patients' illnesses in terms of symptoms and signs throughout PBL in the latter half of first year medicine, placing more emphasis on learning the integrated knowledge he needed, and critically thinking about the information presented in cases.

After his weak performance (46% for the Case 1 Analysis), Chris realised that he needed to learn how to apply his knowledge. Chris' application of his knowledge to cases as he was learning it helped him to understand the information but also helped to develop his clinical reasoning, as he used this information to distinguish the relative likelihood of his hypotheses and detail mechanisms. Chris reported on this approach to learning in second year, commenting that he was "looking at information less this year, and definitely doing a lot more applying of… background knowledge that I already have… (Chris, Interview 3, August 8, 2005). Overall, Chris' principles were to

> *think about the information and learn. There is a wealth of information in medicine, and the most important is to be relevant and to know how to apply it. Always relate whatever you have learnt to the case… try to incorporate it into a bigger picture… always think through what you are learning and… how you're going about learning, instead of just researching the information and… not knowing or understanding the information… not applying it properly and not thinking about how you should… go about learning.*
> (Chris, Interview 3, August 8, 2005).

By second year, Chris commented that "you have to have knowledge… [so] you can do clinical reasoning" (Chris, Interview 3, August 8, 2005). However, Chris had also realized that applying knowledge to reason through "cases helps to build up on your knowledge and helps to reinforce what we have learned", and that with reasoning, "the more practice you get, you tend to remember stuff better" (Chris, Interview 3, August 8, 2005). Chris' knowledge level had more impact on his clinical reasoning when he was able to apply what he was learning. Although Chris' examination scores were high throughout medical school, his applicable knowledge level increased markedly between Case 1 and Case 2 (Table 17) and this had a positive impact on his reasoning ability.

Chris continued to score highly on the case analyses, achieving 74% for both his Case 3 and Case 4 Analysis. According to his second semester PBL tutor in second year medicine, Chris had excellent knowledge and "demonstrated excellent reasoning skills and the ability to use knowledge in a new context…" during class (Chris' PBL Tutor Report, August, 2005). Chris' mechanisms for Case 3 were mostly logical and correct and he also incorporated the relevant information given about the patient's symptoms and signs:

> *genetic disposition and viral molecular mimicry → autoimmunity in which body's immune response attacks own body tissue → chronic inflammation of joint space → inflammatory mediators activate nociceptor → pain perceived, sensitise nociceptor to lower threshold → hyperalgesia → tender to touch, inflammatory mediators cause vascular increased permeability and dilation → increased blood flow in vessels and joints → warm, exudate of fluid in the joint space → swelling*
>
> *chronic inflammation → release of cytokines such as IL-1, TNF-alpha → cytokines prevent release of ferritin from reticuloendothelial cells → decreased Fe in body → Fe not able to use for ATP production → tired and weak, decreased Fe for erthropoeisis → decrease in hemoglobin made → decrease in production of functional RBC → decrease in O2 carrying capacity of blood → anemia → pallor*
>
> *chronic inflammation → release of cytokines such as IL-1, TNF-alpha → induce catabolic state in body and decrease appetite → loss of weight*
> (Chris, Case 3 Mechanisms, June 20, 2005)

The development of Chris' clinical reasoning was also reflected in his second year PBL Tutor report:

> *You are constantly asking questions of students when you can see if something is not making sense or you need further clarification. You offer input in different ways to test certain hypotheses and support your reasoning with proper evidence... your explanations to others are outstanding.*
> (Chris, PBL Tutor Report, June 2005)

The critical thinking skills of interpretation, analysis, evaluation, inference and explanation that Chris displayed in PBL meant that he was able to "systematically develop hypotheses based on existing knowledge and the evidence presented… [and] reassess and rank your hypotheses based on new evidence… by critical analysis" (Chris' PBL Tutor Report, October, 2005). Chris' tutors were identifying strengths in his critical thinking ability which may have led to the development of good clinical reasoning, as evidenced by Chris' TACRR scores for the case analyses (Table 18).

Chris claimed that his clinical reasoning developed “more in a group, especially at this stage and especially PBL and clinical skills, much more than when I was studying alone” (Chris, Interview 3, August 8, 2005). Chris believed that this was due to “doing things, getting into active discussion with your peers and actually having a tutor’s guidance, which is much more beneficial than just studying alone and having to reason to yourself” (Chris, Interview 3, August 8, 2005). Chris described the opportunities provided in a small group:

> *A small group… actually forces you to participate and then you discuss stuff. I guess the discussion would definitely help clinical reasoning because you’re… developing new ideas and actually exploring how different people think differently [about them].*
> (Chris, Interview 3, August 8, 2005)

Chris was described by his second year PBL tutor as a valuable group member who stimulated the development of his peers’ clinical reasoning by critical thinking. “You ask questions constantly to other members of the class to clarify what they mean and add to their thinking as well as testing hypotheses in a systematic way… which keeps the class running well” (Chris, PBL Tutor Report 5, April, 2005). Chris was praised for his critical thinking skill of explanation: students asked Chris “questions whenever they are stuck. You constantly explain any sticky points [and] test certain hypotheses… Your explanations to others are outstanding” (Chris, PBL Tutor Report 5, April, 2005). Chris’ skills in analysis, evaluation and inference were also noted: “when unconvinced of an argument… by effective questioning you have identified weaknesses in arguments… you [are] critical of the information” (Chris, PBL Tutor Report 6, June, 2005). Chris’ critical thinking ability seems to have helped the development of his clinical reasoning and, according to his tutor, also impacted that of the students in his group.

Overall, the development of Chris’ reasoning ability was influenced by improving his ability to make learning issues, developing his relevant knowledge base and changes in his approach to learning and his critical thinking ability. Recognising after Case 1 that his approach to learning did not provide him with an integrated knowledge base that he could use for reasoning, Chris modified his approach. Chris’ reasoning ability was also influenced by his consistent practise of thinking critically during tutorials. By practising critical thinking and the clinical reasoning process, Chris not only developed his own skills of case analysis but perhaps also developed the skills of those in his group.

### 6.4.3 Brianna

Brianna was categorised as a good critical thinker, but changed from having a deep approach to learning to having an ill-defined approach to learning over first year medicine (Table 17). This change in approach to learning was consistent with Brianna becoming less inclined to seek understanding in her learning, and more inclined to learn what she thought would be assessed.

Early in year one medicine, Brianna was concerned with simply reaching a diagnosis, thinking that “the whole point of… Medicine is… trying to find what’s wrong with the patient and fix them” (Brianna, Interview 2, August 23, 2004). Brianna believed that “PBL is sort of structured to resemble real life Medicine, and… real life Medicine is to find a diagnosis” (Brianna, Interview 2, August 23, 2004). Brianna believed that diagnosing was the ultimate goal of PBL, saying that she thought “it…teaches us a way of thinking… we’re…learning to…be doctors. So that’s helping our way of thinking, and it reinforces the whole process…. You feel a sense of achievement at the end if you’ve worked out what’s wrong with the person” (Brianna, Interview 2, August 23, 2004). This understanding of the role of medicine in the context of Brianna’s current learning probably caused her to focus on solving problems rather than clinically reasoning during PBL.

With this view of medicine, Brianna struggled to develop her clinical reasoning ability and make hypotheses, so she relied on other group members to do this:

> *I look for things, to start with what the patients in the cases mention first, because often that will be the most presenting thing to them, and that often will lead to the main cause of the problem… I probably also look to other people in the group as well because I’m still not fully confident with the hypotheses scenario, and see what they’re saying, and then I might build on that. If they mention something on a certain body system and that will start me thinking about that and what else it could be in that.*
> (Brianna, Interview 2, August 23, 2004).

Brianna’s approach to learning was a contributing factor to the difficulty she was having with clinical reasoning. Brianna found Medicine difficult because she was used to breaking information into smaller pieces to learn it. Brianna felt overwhelmed by the "sheer depth and the vast… [breadth] of knowledge" that was required in Medicine: "it's really hard to grasp it all" (Brianna, Interview 2, August 23, 2004). Brianna voiced doubts, saying that sometimes she thought she was "doing too much…[but that it was] hard to know how exactly much to do, how much depth [she needed] to go into" (Brianna, Interview 1, March 29, 2004). However, Brianna did not go into enough depth with her learning and this was reflected by her knowledge level only just being adequate and her mechanisms only sometimes correct for Case 1 (she scored only 5/10 for each of these sections of the Case 1 Analysis).

Brianna listed her hypotheses for the patient's presentation in Case 1 as:

> *Chronic absorption problem in small intestine caused by elevated stress levels: always occurring around exam time.*
>
> *Infection of sigmoid colon by a pathogen: blood, mucous, pain, location*
>
> *Chronic irritation of large intestine causing ulceration of epithelium and hypersecretion of mucous: blood, mucous*
>
> *Change in diet due to exam nerves leading to malabsorption of some food: appetite decrease around exams*
> (Brianna, Case 1 Hypotheses, June 21, 2004)

There is little or no evidence provided for Brianna's first and fourth hypotheses. Brianna's mechanisms for the above hypotheses also were not precise. Partly due to being nervous, Brianna identified that she lacked the ability to make logical hypotheses for Case 1.

> *I'm never sure of how to do hypotheses, that's a really big weakness of mine, and our PBL group was never strong on that anyway. So, I was very unsure of that, but I convinced myself that I would be alright… Because I got the wrong sort of hypotheses that threw the rest of it out, I couldn't develop anything from that. And also I think doing the significance and that, I think down to the pressure as well, I'm alright doing that normally but I think just under the pressure and I wasn't expecting that sort of, I knew that question was coming but I thought it would be a different body system. So that threw me out a little bit.*
> (Brianna, Interview 2, August 23, 2004).

Brianna was not competent at the critical thinking skill of explanation as she found it difficult to detail hypotheses and mechanisms. This was identified by Brianna's tutors who stated that she was not presenting ideas coherently (Brianna, PBL Tutor Report 1, April, 2004). Brianna also identified that she was uncertain about how detailed to make her mechanisms for Case 1.

> *Probably doing the mechanisms as well… our PBL group goes into enormous amount of depth, and I'm not sure if we're supposed to go to that depth… I was not sure of what I was supposed to be doing, and so that uncertainty fed back on to it and I think that really showed through…the mechanisms, I don't think I was quite prepared enough in as much depth as I needed to be.*
> (Brianna, Interview 2, August 23, 2004).

Brianna's mechanisms for the patient's symptoms and signs in Case 1 indicated that her reflections were accurate:

> *Increased stress levels cause an increase in gastrointestinal motility decreasing time for absorption of water from chyme*
>
> *Pathogen invades gastrointestinal epithelium enteropathogenically causing blood and mucus hypersecretion*
>
> *Irritation of the large intestine causes ulceration by causing severe shedding of epithelium and mucus hypersecretion*
>
> *Change in diet near exams causes change in intestine contents leading to a change in the osmotic pressure gradient*
> (Brianna, Case 1 Mechanisms, June 21, 2004)

Although Brianna knew that ulceration and pathogens could play a part in the patient's presentation, she did not provide detail to explain how this could occur. In Brianna's responses, there was no indication of the mechanism by which increased stress levels caused increased gastrointestinal motility, what caused the irritation of the large intestine or what exact change there was in the intestinal content to cause a change in osmotic gradient and why this mattered. As described by her PBL tutor, Brianna needed to "continue to develop skills in presenting information" in order to acquire the critical thinking skill of explanation (Brianna, PBL Tutor Report 2, June, 2004).

Brianna was not integrating her knowledge, as reflected by her low score (5/10) for supporting the reasoning in her mechanisms with clinical information. In Brianna's mechanisms for Case 1, she only sought to explain the blood and mucus in the patient's stools by stating that it was university examination time for the patient. There was little attempt to use other pieces of clinical information in the case (for example the diarrhoea and the urgency to defecate) to support the reasoning in her mechanisms. Compared to other Year 1 students, Brianna only just demonstrated an adequate level of knowledge in this Case 1 Analysis.

Brianna's PBL tutor also recognised and reported that she was having difficulty with the critical thinking skills of interpretation, analysis and evaluation when trying to clarify information or when "re-evaluating hypotheses/differential diagnoses in… response to new information" during class (Brianna, PBL Tutor Report 3, September, 2004). It may be that this difficulty with decoding the significance of information led to Brianna having difficulty with defining hypotheses in Case 1, and her lack of analysis and evaluation skills meant that her mechanistic arguments for the same case contained errors in logic.

Brianna reported that she "got a nasty shock" and "didn't like it at all", when she scored an overall borderline result of 54% for the Case 1 Analysis (Brianna, Interview 2, August 23, 2004). However, it was this result that motivated Brianna to change her approach to clinical reasoning. Not only did Brianna's examination feedback make her conclude that she had been doing "the wrong type of work", but reflections upon her learning in PBL also supported this as she stated that "our problem was we'd have a learning issue, say diabetes, and no specificity of what that related to, and I'd go home and learn a whole pile of statistics and everything and it just didn't work" (Brianna, Interview 2, August 23, 2004).

> *Going into my exams I felt very confident about how I was going to study, and it obviously didn't work… I wasn't expecting to do brilliantly in them but I was probably expecting to do a little bit better than I did. And so that shook me up. I'd been doing heaps of work but I'd been doing the wrong type of work…so I've discussed with other people, and I've been thinking about… the ways that other people have studied… and found out which ways I think were most effective.*
> (Brianna, Interview 2, August 23, 2004).

Brianna's Case 1 Analysis highlighted for her the fact that she learned little when she just copied things from a book and did not connect them with the case or other learning she was doing.

> *During the Semester time I… go home do the learning issues, just work day in day out, and just do that, not reading anything at the end – just file it, and never try and connect anything. During the exams what I did was I went through the objectives, highlighted things I needed to know, and just copied things from the book. So, again, it was just a little copy thing. I never went back and read anything again.*
> (Brianna, Interview 2, August 23, 2004)

This was reflected in Brianna's weak scoring of 4/10 in the Case 1 Analysis for the logic of her mechanisms. As can be seen from the mechanisms, there was no explanation of how a pathogen causes blood and mucus in a patient's stools, how increased stress levels caused an increase in gastrointestinal motility or what caused the irritation of the large intestine. Brianna's PBL tutor had noted that she had trouble researching and discussing mechanisms and basic science and linking knowledge from various disciplines for PBL cases (Brianna's PBL Tutor Report, April, 2004).

However, Brianna showed marked improvement in the ability to detail mechanisms in her Case 2 Analysis (overall TACRR score 78%). For example, there was more detail and correct knowledge and logic in the following mechanism section of Brianna's Case 2.

> *LHF → back up of fluid from left ventricle into left atrium → back up of fluid from left atrium into lungs →*
> *while vertical, fluid gathers at lung bases → as fluid increases, also gathers higher in lungs → creps in mid-zone, decreased surface area for gas exchange → increased CO2 in blood → decreased pH → chemoreceptors triggered → breathlessness and increased respiratory rate, back up of fluid into right heart → back up into vasculature → increased JVP*
> (Brianna, Case 2 Mechanism, November 8, 2004)

Although Brianna's scores for Examination A and B (biomedical knowledge tested in the form of multiple choice and short answer questions or by questions based on human prosections or histological slides) did not improve markedly between Case 1 and Case 2, Brianna showed improvement on the knowledge, mechanistic and logical sections of her Case 2 Analysis compared with her Case 1 Analysis. It was noted by her PBL tutor that Brianna was "able to apply existing and new knowledge to the problem" and was "developing a sound knowledge base" and this may have helped her analysis of the information in Case 2 (Brianna's PBL Tutor Report, October, 2004). Brianna's Case 2 analysis may also have been augmented by her increased skills of analysis, evaluation and inference as she was noted to have a good "approach to testing the hypotheses with evidence in a strategic way" (Brianna, PBL Tutor Report 5, April, 2005).

Although Brianna recognised that developing "clinical reasoning is very important" during second year medicine, she felt that she still struggled with the concept of clinical reasoning and particularly still "struggled with explaining… mechanisms" (Brianna, Interview 3, August 1, 2005). This was borne out by the superficial nature of the mechanisms described in Brianna's Case 3.

> *antigen trigger → autoimmune reaction at joint → acute inflammation → pain, increased vascular permability → oedema at joint, vasodilation → erythema at joint, warmth at joint*
>
> *viral antigen → immune reaction → decreased appetite, weight loss, fatigue, hot and sweaty, continuing autoimmune reaction → rheumatoid arthritis*
>
> *chronic disease → ? → anemia of chronic disease → pale appearance, decreased O2 perfusion of tissue → fatigue*
> (Brianna, Case 3 Mechanisms, June 20, 2005)

Many of the steps expected of a second year medical student were missing in Brianna's mechanisms. For example, there is no explanation for how antigens trigger an autoimmune reaction or how anaemia causes a pale appearance or decreased perfusion of tissue with oxygen. Brianna was still having difficulty with the critical thinking skill of explanation. The detail in Brianna's mechanisms also may indicate a lack of knowledge that has prevented her from developing her clinical reasoning to the level expected of a second year student. Brianna's Examination A and B scores at the time of the Case 3 analysis indicate that her general knowledge level was not high.

In order for her clinical reasoning to develop, Brianna believed that "feedback and just the examples of what other people are doing" was really important (Brianna, Interview 3, August 1, 2005). However, Brianna was still learning to use others questioning her with ‘why?’s to further her reasoning. Brianna did not “mind… being the ‘Why?’ person in the group. But [she didn’t] particularly like it when people [did] it to [her]”, as it forced her to think (Brianna, Interview 3, August 1, 2005). However, although Brianna could see the benefits of someone questioning her reasoning and forcing her to re-evaluate its logicity, she also recognised that “when someone else is doing the ‘Why? Why?’… I’m expecting them to do the reasoning for me”, and this did not help her when she then had to do it on her own, such as in an examination setting (Brianna, Interview 3, August 1, 2005). This lack of development of the critical thinking skills of analysis, evaluation and inference was reported by Brianna’s PBL tutors who noted that although Brianna was able to “logically discuss a problem” and “link information”, her “review of hypotheses and application of new information to the testing of those hypotheses” needed more work (Brianna’s PBL Tutor Report, October, 2005).

This level of performance was evident in the Case 4 Analysis (total score of 55%) and Brianna continued to have difficulty detailing correct hypotheses (criterion score 4/10).

> *ankle/leg swelling, oedema, SOBOE, lung creps + dullness, nocturia, ↑ BP due to a pathology which is causing him to retain fluid, expanding his fluid volume*
>
> *fluid retention and associated signs and symptoms, proteinuria, trace blood in urine due to a pathology affecting his glomerular filtration*
>
> *ankle oedema, SOBOE, lung creps and dullness, nocturia and fatigue due to LHF which has led to RHF*
> (Brianna, Case 4 Hypotheses, November 7, 2005)

Brianna used the case information incorrectly in developing her hypotheses. There was no evidence of congestive cardiac failure (or left heart failure (LHF) leading to right heart failure (RHF)) in the physical examination findings. Brianna did not detail the pathology causing fluid retention or affecting the patient’s glomerular filtration, either. It seems Brianna was still struggling with being able to explain her arguments in hypotheses. This may have been due to a lack of knowledge and could have been influenced by Brianna’s lack of critical thinking skills. Brianna’s PBL tutor stated that she still needed “to work on… hypothesis development and testing" as she had not fully developed the "problem-based critical thinking" skills of analysis, evaluation, inference and explanation (Brianna, PBL Tutor Report 8, October, 2005). Brianna commented that she was having difficulty with "explaining… mechanisms", finding it "difficult because [she is] just not sure what… to be doing" (Brianna, Interview 3, August 1, 2005).

Brianna's lack of knowledge and hence poor performance in Case Analyses 3 and 4 may have been related to her inability to make useful learning issues. Brianna only scored 5/10 for this section of her Case 3 and Case 4 Analyses. Brianna's PBL tutors confirmed that she had difficulty with making learning issues, reporting that Brianna did not "develop concicse learning issues" (Brianna, PBL Tutor Report 7 and 8, September and October 2005). Being unable to determine what to learn during the term may have made it difficult for Brianna to build a knowledge base that she could then use for clinical reasoning.

According to the R-SPQ-2F, Brianna's approach to learning changed from being deep to becoming ill-defined over year one medicine and this was evident in her approach to learning. Brianna's knowledge base increased and she was able to use this knowledge well in Case 2, but by second year medicine Brianna's knowledge base was not adequate for her to explain hypotheses and mechanisms for the patients' symptoms and signs in Cases 3 and 4. Brianna's difficulty with developing useful learning issues may have contributed to this problem. It seems that Brianna's development of clinical reasoning was also affected by her lack of critical thinking skills. Brianna relied heavily upon the group to stimulate her thinking and therefore when alone during examinations, she had difficulty developing the skills of interpretation, analysis, evaluation, inference and explanation when trying to reason clinically. Brianna's ability to analyse the cases did not improve during second year medicine.

### 6.4.4 Frank

Frank was categorised as a deep learner and good critical thinker (Table 17). Similar to the trend of the development of Brianna's clinical reasoning, Frank's clinical reasoning was poor in Case 1 and then improved by Case 2, with overall scores of 40% and 74% respectively for each case analysis. Frank's PBL tutors also noted a change. Initially Frank was "hesitant and unsure about the knowledge he presents, which suggests a less than complete understanding of the material he has researched… [and his] reasoning… is sometimes let down by his apparent lack of understanding" (Frank's PBL Tutor Report, August, 2004). Frank also identified that he lacked the critical thinking skill of interpretation and explanation and stated that his "hypothesis generation… was definitely something I need to work on" (Frank, PBL Journal, May 6, 2004). However, later in first year medicine, Frank's tutor noted that he had had "much more confidence of his own knowledge in recent cases" and was "applying knowledge" well (Frank's PBL Tutor Report, October , 2004).

Frank's lack of understanding about what he was learning was evident in his Case 1 Analysis and his medical knowledge was only just adequate for a first year student. He had limited knowledge about likely differential diagnoses for the patient's presentation and was unable to explain the symptoms and signs the patient presented using a mechanistic approach, as shown in the following examples:

> *Partial obstruction of bowel → peristaltic waves causes distension of bowel → colicky pain each time a wave passes → causes irritation of gastric mucosa and increased motility causing fluid motions to be passed which when passed reduce distension and this reduces pain.*
>
> *Obstruction of diverticulum → bacterial proliferation and inflammation of the diverticulum causing pain in lower left abdomen → inflammation processes causes him to feel hot and sweaty → inflammation extending to involve the large bowel increasing motility → reducing water absorption → diarrhea*
>
> *Inflamed and ulcerated region of the large intestine → irritation causes pain on peristalsis and irritation causes increased intestinal motility → diarrhoea containing blood*
> (Frank, Case 1 Mechanisms, June 21, 2004.)

The logic of some of Frank's arguments is incorrect in these mechanisms. For example, distension of the bowel is not caused by peristaltic waves and colicky pain does not cause irritation of the gastric mucosa. There is little mechanistic explanation for how inflammation causes the patient to feel hot and sweaty, how it causes increased intestinal motility or how it causes blood in the diarrhoea. Frank did not explain some of the clinical data given for the case and use it to support his arguments. The only symptom he explained above was bloody, painful diarrhoea. These are some examples of Frank’s weak reasoning in the Case 1 Analysis (total TACRR score 40%).

Initially, Frank found applying information and reconciling it with the case findings quite difficult. Frank learned that “most of the time if you come up with something irrelevant, someone will pick you up on it” (Frank, Interview 2, August 24, 2004). Other group members would explain to Frank that they had identified a negative finding that made his hypothesis unlikely (Frank, Interview 2, August 24, 2004). Frank relied on the critical thinking skills of his group members for analysis, evaluation and inference to help him through the clinical reasoning process, and did not practise these skills himself. Thus, when alone in the examination, thinking critically for clinical reasoning was difficult.

In first year medicine, Frank’s first semester tutor observed that he was relying on notes in class and that he did not have “confidence in [his] ability to remember the researched material and increase [his] knowledge base” (Frank, PBL Tutor Report 1, April, 2004). It may be that Frank was not learning and understanding material that he was reading for PBL sessions. Therefore, when faced with analysing Case 1, Frank did not have an adequate knowledge base from which to generate appropriate hypotheses.

However, in his Case 2 Analysis, Frank demonstrated much better reasoning (total score 76%). Frank scored well for his hypotheses as they were appropriate and explained the patient’s symptoms (9/10) and his mechanisms were correct (8/10) and logical (8/10) as illustrated in the following example:

> *Cardiogenic shock – likely d/t myocardial infarct ECG is positive finding, ↑BR due to sympathetic stim d/t ↓ tissue perfusion of vital organs.*
>
> *Light headed d/t ↓ blood flow to brain, ↑ pulse rate to try and compensate for ↓ CO d/t ↓ contractility of heart, ↓ BP d/t ↓ contractility + inability to build up pressure in LV, cold peripheries with profuse sweating d/t sympathetic vasoconstriction of peripheral vessels to direct blood to vital organs*
> (Frank Case 2 Hypotheses, November 8, 2004)
>
> *atherosclerotic plaque development in coronary arteries → exposure of endothelial lining under plaque d/t rupture → stim clotting cascade and platelet aggregation → thrombus formation → complete occlusion of coronary vessel → ischaemia + eventual infarction of area supplied by*

> *vessel → stimulation of nociceptors d/t release of cytokines → referred pain to L jaw + elbow d/t convergence of nerves (visceral → somatic) at dermatome, crushing chest pain*
> (Frank, Case 2 Mechanisms, November 8, 2004)

This increase in the ability to analyse a case may be attributable to Frank consolidating his knowledge base. Frank's knowledge level as scored in Examination A and B (biomedical knowledge tested in the form of multiple choice and short answer questions or by questions based on human prosections or histological slides) had increased between Case 1 and Case 2, and it seemed that he was able to apply this knowledge as well, as his TACRR knowledge score also improved from 5 to 8/10 over this time. Frank's tutor commented that he had "been very active in applying past knowledge to the current case" in the latter half of first year (Frank, Tutor Report, October, 2004). Frank stated that he was applying his knowledge in PBL "because I feel that the information will stay with me longer and hopefully I'll remember it better" (Frank, Interview 2, August 24, 2004). It seems that elaborating what he was learning and applying it to cases helped Frank to develop his knowledge base and the ability to use it for clinical reasoning.

However, Frank did not continue this method of building his knowledge base into second year. Frank's PBL tutors presumed that he had knowledge but commented that he was reluctant to participate in class and apply this knowledge to the cases (Frank, PBL Tutor Report September and October, 2005). Although Frank commented that "knowing a lot of stuff and not being able to apply it is completely useless", he had decided that he needed to concentrate on learning his knowledge before applying it (Frank, Interview 3, August 12, 2005). From Frank's knowledge scores (Table 17) it seems that this method was negatively impacting both his ability to build a knowledge base as well as his ability to apply the knowledge that he knew when reasoning through cases, as evidenced by his decrease in Examination A and B and TACRR knowledge scores over second year.

Frank's inability to develop a knowledge base that he could use for clinical reasoning may have been influenced by the difficulty he experienced when trying to make useful learning issues. Initially, Frank's study was driven by the learning issues his PBL group identified: “with everyone coming together and bringing different things… you can have a kind of discussion and see which direction to take for learning issue” (Frank, Interview 1, August 24, 2004). Letting his learning be driven by the group may have disadvantaged Frank when presented with having to make his own learning issues in Case Analysis 1 and he only scored 4/10 for this section. In second year medicine, Frank’s PBL tutors commented that he still could not “develop specific learning issues,… link learning issues to aspects of cases [or] identify further information… to progress the problem” (Frank, PBL Tutor Report 8, October 2005). This was evidenced by the broad learning issues that Frank detailed in his Case 4 Analysis, some of which are given below.

> *1. Types of Heart Failure*
> *2. Management of Heart Failure*
> *3. Investigations and tests to determine the cause of oedema*
> (Frank, Case 4 Learning Issues, November 7, 2005)

Frank only scored 3/10 for this section of his Case 4 Analysis as these learning issues do not help to understand and explain the patient’s symptoms and signs and would not focus Frank’s learning. It may be that Frank’s inability to generate his own specific learning issues disadvantaged the formation of an elaborated knowledge base that he could then use for clinical reasoning.

In second year medicine, Frank’s tutor noted that he was not demonstrating the critical thinking skills of inference and explanation as he still had a “problem of hypothesis generation” and “testing the hypotheses” (Frank, PBL Tutor Report 5, April, 2005). Frank’s tutors also noticed that he did not practise inference or “question material” (Frank, PBL Tutor Report 3, September, 2004). Frank’s hypotheses for Case 4 were not appropriate. For example, there was no evidence of cardiac failure in the physical examination findings and no detail of the pathology causing the patient’s kidney problem was provided:

> *I think he has swelling of his ankles and lower legs and nocturia d/t his heart’s inability to cope with the blood volume resulting in ↑ hydrostatic pressure in capillaries and resultant oedema of legs*

> *I think he has swelling of his ankles and frothy urine with traces of blood in his urine d/t a kidney problem resulting in excretion of proteins + loss of oncotic pressure of capillaries*
>
> *I think he is short of breath on exertion d/t ↑ pressure in his pulmonary capillaries resulting in pulmonary oedema*
>
> *I think he is pale d/t poor oxygenation of his tissues as a result of poor heart function or poor oxygen carrying capacity of his blood – anaemia*
> (Frank, Case 4 Hypotheses, November 7, 2005)

Frank continued to show poor application of his knowledge in describing mechanisms for Case 4. In this case the mechanisms Frank suggested were not very logical (4/10) or correct (4/10).

> *overweight, male, high BP → ↑ likelihood of CVD → ↓ perfusion of heart muscle → ↓ ability for heart to maintain normal function and output → inability to maintain sufficient oxygenation of tissues → pallor, ↑ pressure (hydrostatic) in peripheral capillaries d/t ? → oedema → accumulates in ankles d/t gravity, volume overload of poorly functioning heart → build up of pressure in pulmonary capillaries → pulmonary oedema → SOBOE + fine creps + dull bases*
>
> *kidney → loss of proteins and blood from diseased/poorly functioning kidney → loss of oncotic pressure in capillaries → ↑ movement of fluid into extracellular fluid → oedema accumulation in legs d/t gravity*
>
> *↓ no of red blood cells (if d/t iron deficiency anaemia or blood loss) → ↓ oxygen carrying capacity of blood as ↓ Hb → ↓ oxygenation of tissues → pallor*
> (Frank, Case 4 Mechanisms, November 7, 2005)

Frank considered clinical reasoning to be "very important", but believed it to be "something that just develops almost automatically" (Frank, Interview 3, August 12, 2005). Given this rationale, Frank did not aim to work hard at promoting the development of his clinical reasoning and tutors often commented that he did not demonstrate the ability to "discuss ideas in a logical manner, support individual steps in the reasoning process with relevant findings and specific information, re-evaluate hypotheses in response to new information/discussion… or ask questions to help to clarify the problem" (Frank's PBL Tutor Report, April, 2005). Frank's PBL tutors noted that he was often very quiet during tutorials and reminded him that he needed "to be actively involved in all sessions" in order to promote the development of his clinical reasoning: "if you do not test your abilities within the tutorials, how then do you know if you have the knowledge?" (Frank, PBL Tutor Reports, October, 2005).

There was often a gap in Frank's knowledge base and he did not practise critical thinking skills of interpretation or seek to "clarify the significance" of information during PBL (Frank, PBL Tutor Report 8, October, 2005). Frank did not demonstrate development of his ability to test hypotheses or analyse and evaluate information (Frank, PBL Tutor Report 8, October, 2005). This lack of knowledge and critical thinking ability was a factor that contributed to the limited development of Frank's clinical reasoning ability and he only achieved scores of 57% and 46% for his Case 3 and Case 4 Analysis, respectively.

Overall, Frank's clinical reasoning did not tend to develop over first and second year medicine. Frank did not understand what clinical reasoning involved and he focussed on acquiring notes of information without necessarily learning, applying and integrating this knowledge as he reasoned through a case. Frank had demonstrated only a limited ability to think critically about his cases and develop learning issues and he often relied on other group members to do these tasks for him. For these reasons, Frank had not developed the skill base to be able to reason independently during examinations.

### 6.4.5 Hannah

Hannah was a deep learner and good critical thinker (Table 17). During first semester in year one, Hannah demonstrated good clinical reasoning (total score 85% for the Case 1 Analysis). Hannah described clinical reasoning as

> *the use of medical knowledge or physiology, anatomy – things like that – to work through a medical problem that someone presents with so being able to use all the knowledge that you've sort of got from textbooks and things like that to be able to apply it to the clinical setting and sort of be able to explain a person's disease, to be able to treat it, manage it.*
> (Hannah, Interview 3, August 5, 2005).

Hannah believed clinical reasoning was "the most important skill that you have to have… as a doctor because that's how you work through patients' problems. That's the basis of it all" (Hannah, Interview 3, August 5, 2005).

Hannah claimed that she had the critical thinking skill of interpretation. She initially found it "quite easy to… pick out the points that might… be related", and this was certainly evident in her Case 1 Analysis. Hannah was able to achieve high scores for identifying the relevant information in the case and using it in the hypotheses with appropriate weighting (8/10) (Hannah, Interview 2, August 30, 2004).

> *I think Mr Bush has inflammatory bowel disease*
> *<u>Supporting Data</u> – blood and mucous in stool (from ulceration, but only this time – not before – is diarrhoea from stress highlighting this), age and male, exacerbated by stressful situations, pain on distension → relief after motion.*
>
> *I think Mr Bush has a tumour in the large bowel*
> *<u>Supporting Data</u> – abdo pain before motion – tumour → build up → distension, relief on defecation, diarrhoea associated with stress exacerbates its presence, blood/mucous – invasion into submucosal layer.*
>
> *I think Mr Bush has diarrhoea due to bacterial infection*
> *<u>Supporting Data</u> – symptoms during stressful situations – exams (3 times) - ↑ susceptibility to invasion, blood and mucous (invasive)*
> *<u>BUT</u> – this is ↓ likely as → no systemic symptoms of inflammation, can't be TD, diarrhoea 3 similar times → chronic.*
> (Hannah, Case 1 Hypotheses, June 21, 2004).

Hannah believed that she'd learnt "the importance of not working from the diagnosis but working from the actual physiology" (Hannah, PBL Journal, May 6, 2004). The fact that PBL was a model of clinical reasoning also helped Hannah in her learning: "the layout – like session by session… the structure of it [PBL] does make you think about it in that way" (Hannah, Interview 3, August 5, 2005).

> *In PBL it's helpful to explain the symptoms. Rather than looking at diseases it's helpful to look at how, for example, does a headache come about, the different ways for that, and then from that – once you look at all the symptoms and say "Well, that can be caused by this, this and this" you can piece it together and see how they fit together and what disease that that might be involved in.*
> (Hannah, Interview 3, August 5, 2005).

Hannah's understanding of the PBL process was aligned with the model of the course. Although Hannah understood what was required, she identified that she still needed to practise applying information to a case and creating a mechanism for her hypotheses: "the structuring of information into a mechanism… is something I have to continue to work on" (Hannah, PBL Journal, May 6, 2004). In an interview, Hannah was also unable to articulate what caused her to learn how to reason clinically, saying "it just happens" (Hannah, Interview 2, August 30, 2004). This belief may have been a reason that Hannah did not make a concerted effort to practise clinical reasoning during PBL sessions. Hannah's tutor report revealed that she was advised of her "lack of participation in discussions" and reminded that "she might get more from the sessions if she became a bigger player" (Hannah, PBL Tutor Report 1, April 2004).

Hannah used a pattern matching approach for her learning and reasoning through cases, although she knew that it was "probably not the way it's meant to work a lot of the time… you're meant to look at the symptoms and work from that but it's easier when you get the diagnosis" (Hannah, Interview 2, August 30, 2004). "If you've got the title of diabetes, then you can go home and read about diabetes and from what you read you can fit it back to the case" (Hannah, Interview 2, August 30, 2004). By applying the diagnosis first, Hannah was then able to focus her learning and develop an understanding of the case:

> *The last couple of cases we've had we've been given the diagnosis straight away and that's easy because you've got your starting point there. Whereas when you get your diagnosis, like, towards the end, it's a lot harder because you sort of have to look at all the differential diagnoses.*
> (Hannah, Interview 2, August 30, 2004)

Hannah was using a problem-solving approach, rather than engaging in problem-based learning to develop her clinical reasoning. Thus Hannah was understanding information only by working back from the solution and so she was not developing clinical reasoning skills. This was consistent with Hannah's case analyses scores of only 52%, 44%, and 50% for Case 2, 3 and 4, respectively.

Hannah found developing her knowledge base for reasoning to be a challenge because there were "different aspects that you… have to look at and consider… coming from a knowledge base of basically nothing [and then having] to apply… gynaecology and pathology and anatomy and physiology [to the case at hand and fit] things together and be able to understand them [was] hard" (Interview Hannah, Interview 2, August 30, 2004). This process of applying information and reasoning was difficult for Hannah and she also described developing her clinical reasoning as “really overwhelming” (Hannah, Interview 3, August 5, 2005):

> *It’s just got all these different skills. You have to have the knowledge. You have to have analytical skills. You have to be able to synthesise information. You have to be able to do all these different things… if you can’t analyse the information then you’re stuck.*
> (Hannah, Interview 3, August 5, 2005).

Applying integrated knowledge and using critical thinking skills to reason through cases was daunting for Hannah, and she did not practise this during PBL sessions. This continued to be an issue in second semester of first year medicine, as it was identified by Hannah’s tutor that she did not contribute, and therefore there was no evidence that she could apply her knowledge or test her hypotheses (Hannah’s PBL Tutor Report, September, 2004).

Hannah was unable to apply her knowledge to Case 2. Hannah had difficulty detailing appropriate hypotheses (3/10) and her knowledge level was only just adequate for a year one student at this time (6/10).

> *I think he has [crushing chest pain, referred chest pain, unchanged 1hr on rest, radiates to L arm/jaw, not back, difficulty breathing last ½ hr, lightheaded on standing/walking, male, age 49, overweight, sweat and vomit] due to a myocardial infarction which decreases function of heart and heart failure leads to accumulation in the lungs*
> *Supporting Data*
> *- Male/age/overweight – RFs for heart disease/CAD*
> *- Chest pain characteristic of heart, unchanging/onset at rest means not angina, but more likely MI, referred pain*
> *- ↑ rate/difficulty breathing and crepitations – heart failure → fluid in lungs*
> *- OE*
> *- peripheral (not central) cyanosis → circulation prob ie heart ↓ efficiency*
> *- audible 3rd HS → heart malfunction*
> *- leg pulses below femorals difficult → atherosclerosis?*
> *- ECG – MI confirmed*
> *Detract*
> *- Apex beat not palpable → ↓ likelihood LV hypertrophy (BUT overweight – could be hard to feel)*
>
> *I think he has [central chest pain on rest and no previous similar episode, difficulty breathing last ½ hr, overweight] because of pulmonary embolism*
> *Supporting Data*
> *- chest pain, ↑ breathing*

*Detract*
*- referred pain, timeframe – would have been breathless sooner*

*I think he has [central chest pain on rest after lunch/beer, no previous similar episode, lightheaded on standing/walking, vomit partially digested food and meds – reflux 2 yrs] because of an oesophageal varice*
*Supporting Data*
*- age*
*- chest pain, history of reflux, lightheaded on standing/walking/ sweating synonymous with shock (from blood loss)*
*Detract*
*- no blood in vomit [therefore very unlikely]*

*I think he has [central chest pain on rest after lunch/beer, no previous similar episode, lightheaded on standing/walking, age 49 and meds – reflux 2 yrs ] because of a peptic ulcer*
*Supporting Data*
*- chest pain, history of GI prob (reflux), signs of shock – lightheaded, sweat, ↑ HR etc.*
*Detract*
*- no blood in vomit [therefore very unlikely]*
(Hannah, Case 2 Hypotheses, November 8, 2004).

Although Hannah's first hypothesis is correct, the students were given the diagnosis of myocardial infarction in the examination paper, and so the other hypotheses she listed were highly unlikely and in some cases almost incompatible with the clinical data. In keeping with her problem-solving approach, Hannah listed diagnostic hypotheses and no mechanistic hypotheses to explain the patient's symptoms and signs. Given that the patient already had a diagnosis, Hannah's ability to demonstrate her clinical reasoning in this context was limited.

Hannah's inability to apply knowledge also limited her detailing of mechanisms (5/10) for Case 2.

*Pulmonary Embolism*
*age, overweight, male → stenosis of pulmonary tricuspid valve → plaque bk off → lodges in lungs → fluid to lungs → distension C-fibres → chest pain, ↑ breathing*

*Oesophageal Varice and Peptic Ulcer as lunch/food, age = 49, Reflux/GI problem → oesophageal varice, peptic ulcer, erode to submucosa, chest pain (but ↓ likelihood 'crushing', bleeding <u>NB no signs of bleeding</u> → hypovolemia → baroreceptors detect ↓ pressure → SNS stimulation, sweating, ↑ HR, ↑ tone of vessels, ↑ Tot. Per. Resist & ↑ venous return → ↑ CO, vessels already constricted so can't constrict more → ↓ perfusion of brain → lightheaded on standing*

(Hannah, Case 2 Mechanisms, November 8, 2004).

Rather than being able to explain mechanistic hypotheses, such as left and right heart failure causing crepitations and raised jugular venous pressure, or the development of a thrombus in the coronary arteries causing myocardial infarction, Hannah justified her diagnostic hypotheses. Some of the justification for these mechanisms was not very logical, as there was no explanation of the pathogenesis of atherosclerosis, nor any explanation of how reflux may have caused an oesophageal varix. Hannah may have known the information needed for Case 2, but did not apply the information to the case at hand, having not practised this skill.

Hannah recognised that she needed to "pay more attention to detail… a lot of the time I sort of get the… general overview but then when it comes to looking at the actual details of why 'This leads to this' I sort of tend to neglect that" (Hannah, Interview 3, August 5, 2005). However, Hannah believed her clinical reasoning had "become a lot easier because [she'd] developed that background knowledge" (Hannah, Interview 3, August 5, 2005). According to Hannah's Examination A, B and C scores (for biomedical knowledge tested in the form of multiple choice and short answer questions, by questions based on human prosections or histological slides or by modified essay questions, respectively) in first and second year, her knowledge level was quite high. However, Hannah did not apply her knowledge base as she was learning it, stating that she just concentrated on "learning the information… because I want to have that knowledge behind me before I go applying it to a clinical setting" (Hannah, Interview 3, August 5, 2005). Hannah's PBL second semester, year two tutor noticed that she did not integrate her knowledge and encouraged Hannah in "actively incorporating… her learning" (Hannah, PBL Tutor Report 7, September, 2005). It seems from Case Analyses 2, 3 and 4 that even though Hannah may have known information, she could not apply it to the cases at hand.

Initially, Hannah was able to detail useful learning issues, scoring 8/10 for this section of her Case 1 Analysis. However, Hannah found it difficult to detail useful learning issues in her subsequent case analyses, scoring only 3/10, 2/10 and 3/10 for this section in Case 2, 3 and 4 respectively. Example of Hannah's learning issues for Case Analysis 4 are given below.

*1. How will this patient be immediately managed?*
*2. Does aspirin have any effect on the kidneys?*
*3. What is his prognosis if this is a kidney pathology?*
(Hannah, Case 4 Learning Issues, November 7, 2005)

Hannah's learning issues were broad and did not focus on explaining the mechanisms for the patient's most important symptoms and signs. Although even a superficial glance at Hannah's mechanisms for Case Analyses 2, 3 and 4 highlight that there were numerous areas where her knowledge was deficient, Hannah only listed a few learning issues for each case. It may be this lack of understanding about where her knowledge was deficient that prevented Hannah from developing a knowledge base that she could apply for clinical reasoning. Hannah's first year medicine PBL tutor reported that she struggled to "link learning issues to aspects of the case" (Hannah, PBL Tutor Report 4, October 2004). Hannah's second year medicine PBL tutor also confirmed that she could not "identify further information… to progress the problem" (Hannah, PBL Tutor Report 7, September 2005).

Hannah claims that she found the examination feedback she received to be useful (Hannah, Interview 3, August 5, 2005). This feedback was the only factor that alerted Hannah to the fact that she was having problems with her reasoning. "I thought I'd done okay but when I came back and read comments… it showed me that I've still got gaps in my reasoning processes and it showed that I lacked detail" (Hannah, Interview 3, August 5, 2005). However, Hannah's clinical reasoning did not seem to have developed much further by Case 3 as she was still unable to make mechanistic hypotheses when she was given the diagnosis (Case 3).

*I think she has a widespread autoimmune inflammatory condition affecting her joints (Rheumatoid Arthritis)*

*I think she has SLE, which has caused a widespread autoimmune inflammatory condition mainly affecting her joints*
(Hannah, Case 3 Hypotheses, June 20, 2005)

For a second year medical student, these hypotheses had inadequate detail and did not explain in the depth necessary how the patient's symptoms and signs came about. Hannah either did not have sufficient knowledge to complete this activity or she was unable to apply the knowledge she had, as evident in the following mechanisms:

> *trigger? virus? → autoantibodies activated against an unknown antigen in joints → acute inflammation of the small joints → inflammation of surrounding tissues eg ligament, muscle → pain, over time, spread with large joint involvement, warmth, pain, swelling, tenderness of joints, erosion of cartilage of joints → bone no longer 'protected' by cartilage → bone to bone contact → pain*
>
> *unknown antigen → autoantibodies act against antigen in joints → as per RA mechanism, autoantibodies act against antigen in skin, eyes, lung etc → widespread inflammatory conditions/symptoms*
> (Hannah, Case 3 Mechanisms, June 20, 2005)

A review of Hannah's tutor report revealed that she was advised that it was "difficult to gauge" her "clinical reasoning due to a lack of participation in discussions" (Hannah, PBL Tutor Report 1, April 2004). Hannah was reminded that, "as the reasoning aspect of PBL occurs in a largely informal manner, those that don't contribute to group discussion really don't get a chance to develop their own reasoning skills" (Hannah, PBL Tutor Report 7, September 2005). Hannah's lack of participation meant that she was not developing critical thinking skills during PBL sessions. Although she was encouraged to interpret information by asking more questions and to practise evaluation and analysis of hypotheses, there is no evidence that a tutor saw Hannah subsequently demonstrating these abilities (Hannah, PBL Tutor Report 8, October, 2004).

This inability to think critically during reasoning is evidenced by Hannah's Case 4 Analysis score of only 50%. For example, Hannah's Case 4 hypotheses were:

> *I think he has a kidney pathology resulting in raised blood pressure, swelling and frothy urine*
>
> *I think he has hypertension which has resulted in kidney damage and cardiac failure on exertion*
> (Hannah, Case 4 Hypotheses, November 7, 2005)

In these hypotheses, Hannah did not detail the pathology causing the patient's kidney problem and as there was no evidence of cardiac failure in the physical examination findings. As a consequence, Hannah scored 4/10 for this section of the Case 4 Analysis.

Hannah's PBL tutor was concerned that because she "wasn't very involved in these discussions… her reasoning skills… need significant improvement" (Hannah, PBL Tutor Report 7, September, 2005). Hannah's reticence to practise clinical reasoning in PBL tutorials significantly disadvantaged the development of her clinical reasoning. Hannah's inability to make useful learning issues, to gauge the level of detail she needed to learn and to apply the knowledge she did learn also made it difficult for her to perform well in the case analyses. Hannah's limited use of critical thinking skills to reason through cases also seemed to hinder her clinical reasoning development. Overall, Hannah's ability to analyse cases did not improve during the first two years of medicine.

## 6.5 CHAPTER SUMMARY

These case studies provide further validation of TACRR as a measure of clinical reasoning. Students' scores on this instrument were consistent with insights gained about their reasoning development from a review of their interviews, PBL journals and PBL tutor reports.

Extrapolation of the case study data highlighted that reflecting upon the modelling of clinical reasoning had an impact upon the development of students' clinical reasoning. Alison, Chris and Brianna all recognised that clinical reasoning was important and that it was encouraged and modelled by the course structure and assessment. This stimulated Alison and Chris in particular to make developing clinical reasoning one of their primary aims of medical school. In contrast, Frank and Hannah tended to be less aware that modelling of clinical reasoning was occurring and this may have impacted their development of this set of skills.

The case study data also indicated that practising clinical reasoning was a factor that influenced students' developing this set of skills. Alison and Chris were noted to be actively involved in reasoning during PBL tutorials and both students reported practising clinical reasoning when studying individually. By practising in class, Alison and Chris were afforded opportunities to receive feedback on their reasoning, which helped to develop their skills. Reasoning clinically when alone made these students practise all of the skills involved in this process, and thus Alison and Chris were able to perform well on all clinical reasoning criteria. Students such as Brianna, Frank and Hannah did not often practise reasoning in class and hardly ever practised reasoning clinically during individual study. This meant that these students did not develop strengths in some areas of clinical reasoning and found it very difficult to demonstrate competency for all clinical reasoning criteria in the examinations.

Another factor influencing students' clinical reasoning development was their critical thinking ability. Alison and Chris both demonstrated the ability to think critically about their own arguments when alone and also those of others when in class. Using critical thinking skills when reasoning was reported by the students and their tutors as having a positive impact on the development of Alison's and Chris' clinical reasoning ability. Brianna, Frank and Hannah found it difficult to think critically about their reasoning. However, these students also reported that observing others think critically about arguments helped them to develop this disposition and therefore improve their clinical reasoning ability.

Knowledge level was also highlighted as a factor that affected clinical reasoning development in these case study students. However, it was the elaboration of students' knowledge and their ability to apply it to cases that had the greatest impact on their development of clinical reasoning. Alison and Chris, good clinical reasoners, had a high knowledge level according to their examination scores. However, Hannah also achieved high examination scores for knowledge, and she was weak at clinical reasoning. Alison and Chris' dedication to applying their knowledge to cases as they learnt it (as evidenced by their interviews and tutor reports) meant that they were able to elaborate their knowledge base and retain information that they could then apply to reason through new cases (as evidenced by their TACRR knowledge scores). In contrast, Hannah, Frank and Brianna tried to learn information without simultaneously applying it to cases. As evidenced by their TACRR knowledge scores, Hannah, Frank and Brianna did not build a base of applicable knowledge. This may have hindered the development of their clinical reasoning.

A student's approach to learning was also reported to be a contributing factor to clinical reasoning development. Alison and Chris' practice of integrating and applying knowledge to cases as they learnt it helped them to retain this knowledge and also know how to apply it to future cases. In contrast, Brianna, Frank and Hannah found it difficult to integrate their knowledge and this hindered their ability to apply information to cases. Not integrating and applying information as they learnt it also seemed to make it more difficult for Brianna, Frank and Hannah to apply their knowledge in future cases.

# CHAPTER SEVEN - THE COLLATED RESULTS

## 7.1 INTRODUCTION

Further analysis of both the qualitative and quantitative data provided additional evidence to address the research questions for this study. In particular, this chapter explores the factors which contributed to the development of students reasoning ability.

## 7.2 THE DEVELOPMENT OF CLINICAL REASONING

TACRR's potential to measure the development of clinical reasoning was investigated using a Kruskal-Wallis test. The Kruskal-Wallis non-parametric test was used as the data was measured on nominal or categorical scales involving three or more groups. The student cohorts investigated were Year 1, 2004 ($N$ = 113) and Year 2, 2005 ($N$ = 113).

In order to compare the characteristics of students' with different clinical reasoning ability, students in each cohort were categorised into one of three groups (see Table 19) according to their percentage increase in TACRR scores between one case analysis and the next (Case 1 and 2 for the Year 1, 2004 cohort and Case 3 and 4 for the Year 2, 2005 cohort). The percentage increase in TACRR score between one case analysis (X) and the next (Y) was calculated according to the following equation:

$$\frac{\text{Score for Case Y Analysis} - \text{Score for Case X Analysis} \times 100}{\text{Score for Case X Analysis}} = \text{Percentage Increase in Score}$$

Table 19 - Students' Clinical Reasoning Ability Groups According to the Percentage Increase in Their TACRR Scores for the Case Analyses

| Clinical Reasoning Ability Group | | Student's Percentage Increase In TACRR Score Between The Two Case Analyses |
|---|---|---|
| I | Improved | ≥ 5% |
| II | No Change | - 4.9% to 4.9% |
| III | Worsened | ≤ - 5% |

The five percent cut off in percentage change in TACRR scores between the two case analyses was chosen for the categorization process as this was the average percentage change of the 2004 first year medical students between Case Analyses 1 and 2. As students in each cohort were categorised according to one of three Clinical Reasoning Ability Groups (see Table 19), each Kruskal-Wallis Test has 2 degrees of freedom (df). As Type I errors due to the heterogenous variance of groups even in the non-parametric Kruskal-Wallis Test can increase by fifty percent at the 0.5 and 0.01 significance level ($p$), the significance level used for results of the Kruskal-Wallis Test is this study has been set at $p < 0.001$ (Zimmerman, 2000).

A summary of the TACRR question and section scores (see Chapter Four and Appendix D for an explanation of TACRR sections) that were significantly different between the cohorts' Groups I, II and III is given in Table 20. As shown in Tables 21 and 22, there was a significant ($p < 0.001$) difference between the Year 1, 2004 Cohort's Groups I, II and III's scores for every TACRR question and TACRR section of the Case 2 Analysis. These scores were all given as percentages. An inspection of the mean ranks for the groups suggested that Group I had the highest scores and Group III the lowest scores for each criterion that was significantly different. This suggested that students identified by TACRR as having better clinical reasoning by Case 2 showed development of all areas of clinical reasoning.

Table 20 - Differences Between Case Analysis Groups' Clinical Reasoning Groups I, II, and III's Improvement in Clinical Reasoning

| **Cohort** | **TACRR Section with Significant Difference in Group I, II and III scores** | **TACRR Question with Significant Difference in Group I, II and III scores** | **Description of Clinical Reasoning Skill with Significant Difference in Group I, II and III scores** |
|---|---|---|---|
| Year 1 2004 | All | All | All |
| Year 2 2005 | A | 3 | Detailing appropriate hypotheses |
| | C | 6 | Detailing logical steps in mechanisms |
| | D | 8 | Describing useful learning issues |
| | E | 10 | Overall approach to the case |
| | Not applicable | Total | All |

Table 21 - Differences in TACRR Percentage Scores between Students of Varying Clinical Reasoning Ability

| **Component of TACRR** | **Year 1 Mean TACRR % Score (Standard Deviation)** | | | | | | **Year 1 p** | **Year 2 Mean TACRR % Score (Standard Deviation)** | | | | | | **Year 2 p** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Group I N = 54** | | **Group II N = 17** | | **Group III N = 42** | | | **Group I N = 32** | | **Group II N = 16** | | **Group III N = 65** | | |
| Question 1 | 73.3 | (14.0) | 67.1 | (14.0) | 59.0 | (18.7) | < 0.001 | 68.8 | (12.4) | 66.3 | (12.0) | 61.5 | (9.6) | < 0.01 |
| Question 2 | 65.7 | (18.5) | 54.7 | (15.5) | 45.0 | (20.9) | < 0.001 | 69.4 | (11.9) | 65.6 | (10.3) | 58.3 | (16.2) | < 0.01 |
| Question 3 | 66.5 | (21.9) | 50.6 | (13.9) | 41.9 | (20.7) | < 0.001 | 55.9 | (17.6) | 46.3 | (15.0) | 40.3 | (15.9) | < 0.001 |
| Question 4 | 45.2 | (27.0) | 32.9 | (27.3) | 20.5 | (24.4) | < 0.001 | 47.5 | (13.2) | 45.0 | (15.5) | 42.2 | (14.2) | > 0.05 |
| Question 5 | 61.4 | (14.7) | 52.9 | (10.4) | 40.6 | (15.5) | < 0.001 | 50.8 | (11.7) | 47.5 | (12.4) | 43.3 | (11.9) | < 0.05 |
| Question 6 | 63.5 | (14.7) | 52.4 | (13.3) | 42.6 | (17.4) | < 0.001 | 56.3 | (11.3) | 53.1 | (14.5) | 48.0 | (11.8) | < 0.01 |
| Question 7 | 72.0 | (13.9) | 64.1 | (10.6) | 57.6 | (18.1) | < 0.001 | 64.4 | (8.8) | 59.4 | (13.4) | 55.8 | (11.4) | < 0.01 |
| Question 8 | 50.4 | (17.9) | 35.3 | (15.5) | 30.5 | (19.6) | < 0.001 | 51.3 | (16.6) | 50.6 | (19.1) | 36.3 | (17.0) | < 0.001 |
| Question 9 | 64.9 | (14.1) | 55.3 | (10.5) | 45.2 | (15.1) | < 0.001 | 56.0 | (11.3) | 52.9 | (10.7) | 46.8 | (10.9) | < 0.01 |
| Question 10 | 66.9 | (12.6) | 54.7 | (10.1) | 45.0 | (16.0) | < 0.001 | 68.4 | (9.5) | 61.9 | (11.7) | 58.2 | (11.3) | < 0.001 |
| Total | 62.9 | (12.4) | 52.1 | (9.0) | 42.8 | (13.9) | < 0.001 | 58.8 | (9.2) | 54.8 | (10.2) | 49.1 | (9.6) | < 0.001 |

Table 22 - Differences in TACRR Section Percentage Scores between Students of Varying Clinical Reasoning Ability

| **Component of TACRR** | **Year 1 Mean TACRR % Score (Standard Deviation)** | | | **Year 1** | **Year 2 Mean TACRR % Score (Standard Deviation)** | | | **Year 2** |
|---|---|---|---|---|---|---|---|---|
| | **Group I N = 54** | **Group II N = 17** | **Group III N = 42** | **p** | **Group I N = 32** | **Group II N = 16** | **Group III N = 65** | **p** |
| Section A | 62.7 | 51.3 | 41.6 | <0.001 | 60.4 | 55.8 | 50.6 | < 0.001 |
| Hypothesis Generation | (15.6) | (12.7) | (15.3) | | (10.8) | (11.4) | (10.6) | |
| Section B | 61.4 | 52.9 | 40.6 | <0.001 | 50.8 | 47.5 | 43.3 | < 0.05 |
| Correctness of Mechanisms | (14.7) | (10.4) | (15.5) | | (11.7) | (12.4) | (11.9) | |
| Section C | 67.8 | 58.2 | 50.1 | <0.001 | 60.3 | 56.3 | 51.9 | < 0.001 |
| Reasoning in Hypotheses and Mechanisms | (13.4) | (11.0) | (16.5) | | (9.1) | (13.5) | (10.4) | |
| Section D | 50.4 | 35.3 | 30.5 | <0.001 | 51.3 | 50.6 | 36.3 | < 0.001 |
| Learning Issues | (17.9) | (15.5) | (19.6) | | (16.6) | (19.1) | (17.0) | |
| Section E | 65.9 | 55.0 | 45.1 | <0.001 | 62.2 | 57.4 | 52.5 | < 0.001 |
| Overall Knowledge and Approach | (12.8) | (9.8) | (15.2) | | (10.0) | (10.3)) | (10.6) | |

As shown in Table 21 and 22, there were also significant differences in the Year 2, 2005 Cohort's Groups I, II and III's TACRR scores for the Case 4 Analysis. There was a significant difference between the three groups' scores for TACRR questions three, eight, ten, the total TACRR score and all TACRR sections except the correctness of mechanisms. An inspection of the mean ranks for the groups suggested that Group I had the highest scores and Group III the lowest scores for each criterion that was significantly different. This suggested that although in general students' clinical reasoning develops globally as they progress through second year medical school (significant differences arise between Groups I, II and III's scores for their overall approach to the case (question ten) and their total TACRR scores), specific components of clinical reasoning ability with significant difference in development across Groups I, II and III were limited to appropriate hypothesis generation and making useful learning issues. These results highlighted that these clinical reasoning skills were the most difficult for students to master.

Evidence from the case studies supported the assertion that generating hypotheses was a skill that weaker clinical reasoners found difficult to develop. Frank identified in first year that his "hypothesis generation was definitely something I need to work on" (Frank, PBL Journal, May 6, 2004). This skill continued to be difficult for Frank to develop, as in second year his PBL tutor commented that he still had a "problem of hypothesis generation" (Frank, PBL Tutor Report 7, September, 2005). Similar to Frank, Brianna, an average clinical reasoner, said that she was "never sure of how to do hypotheses, that's a really big weakness of mine" (Brianna, Interview 2, August 23, 2004). Hypothesis generation was still noted to be a weakness by Brianna's PBL tutor in second year, as they instructed her to continue "to work on… hypothesis development" (Brianna, PBL Tutor Report 8, October, 2005).

Evidence from the case studies also supported the assertion that making useful learning issues was a skill that weaker clinical reasoners found difficult to learn. Rather than making learning issues about the steps that they could not explain in their mechanisms for a patient's symptoms and signs, both Brianna and Hannah waited until they had a diagnosis for the case and then researched this disease process. Brianna realised that this was not good practice, stating that "our problem was that we'd have a learning issue, say diabetes, and no specificity of what it was related to, and I'd go home and learn a whole pile of statistics and everything and it just didn't work" (Brianna, Interview 2, August 23, 2004). This approach meant that Brianna and Hannah's learning was not integrated or applied to the case, and they found it much harder to retain this information and apply it when reasoning through future cases. Similarly, Frank's reliance on using learning issues developed by other members of his group meant that he found it difficult to generate an applicable knowledge base for clinical reasoning, as well as develop learning issues in examination situations.

### 7.2.1 Section Summary

Overall, TACRR was useful as a tool to investigate the development of clinical reasoning (see discussion above and evidence of validity and reliability in Chapter 4). In first year medicine, students who developed clinical reasoning ability demonstrated improvement for all their clinical reasoning criteria. However, during second year medicine, differences in students' clinical reasoning development were most marked for the criteria of hypothesis generation and making useful learning issues. Further evidence that first year students who developed their clinical reasoning ability were better at all the clinical reasoning skills and that some clinical reasoning criteria were more difficult to develop in second year than others was gleaned from the case studies.

## 7.3 FACTORS THAT IMPACT ON THE DEVELOPMENT OF CLINICAL REASONING

Chapter Six detailed five case studies conducted as part of this research. Extrapolation of these data revealed five themes that had an impact on the development of clinical reasoning ability, namely (1) reflecting upon the modelling of clinical reasoning, (2) practising clinical reasoning, (3) critical thinking about clinical reasoning (4) applying knowledge for clinical reasoning and (5) the approach to learning for clinical reasoning. These extrapolations were supported by information from further student interviews.

### 7.3.1 Reflection Upon the Modelling of Clinical Reasoning

The modelling of clinical reasoning emerged as an important factor that helped students to develop their own clinical reasoning ability. The importance of clinical reasoning was modelled by the course structure and this set of skills was also modelled in clinical skills teaching sessions and PBL tutorials. However, in order for the modelling of clinical reasoning to affect students' own clinical reasoning development, they needed to recognise that this modelling was taking place and reflect upon the importance of clinical reasoning.

#### *7.3.1.1 The Course Structure and Assessment Practices*

The designers of the medical curriculum recognised that developing clinical reasoning was an important part of becoming a competent doctor, and therefore promoted the development of clinical reasoning by having an integrated course structure and assessment process. Students' motivation to develop a set of skills is often affected by how important they see these skills to be. Evidence from the student interviews suggested that students who recognised the fact that the course structure promoted the development of clinical reasoning were those who reflected upon the importance of clinical reasoning and were able to define this concept. These students made developing this set of skills one of their most important aims during medical school and also became better at clinical reasoning.

Alison was a good clinical reasoner who, among other students, recognised that clinical reasoning was promoted by the integrated curriculum. Alison stated that clinical reasoning was "something that comes naturally from this course" and could recognise that "this course is structured to develop it" (Interview 42.1, August 4, 2005). A similar view was reported by another student with good clinical reasoning ability:

> *There's quite a focus on [clinical reasoning] in the course… it encourages you to think about it… The way it all links together… you know if you're doing a case in PBL and you learn something in resource you think I can apply this to that and it helps to create a bigger picture… that helps you [with] the reasoning of it.*
> (Interview 53.1, August 1, 2005).

Yet another student commented that "the PBL process… really does aim at… developing good clinical reasoning" (Interview 15.2, August 4, 2005). Due to the integrated nature of the course, the knowledge acquisition and reasoning from PBL was then encouraged in the Clinical Skills Teaching Sessions. One student recognised that this was done and reasoned that it was “so that we can apply our knowledge… all of the different areas we’ve covered ties in with what we’re doing in clinical skills… we can think back to what we’ve done so far and hopefully apply it” (Interview 48.1, August 3, 2005).

However, not only is the course integrated, in order to promote the development of clinical reasoning, the assessment of the course is integrated. As good clinical reasoning students observed, the integrated assessment of the course rewarded clinical reasoning.

> *The [emphasis on] clinical reasoning disguises itself… some of the questions in the exam you need to be thinking about all of this information and all of that and to be able to fulfil the question you need to use your clinical reasoning but at the same time you’re not sitting there thinking “Oh, how do I reason this out?” It’s just something that comes.*
> (Interview 42.1, August 4, 2005)

In contrast, Brianna, an average clinical reasoner, initially failed to appreciate the integration of the course assessment and the way it assesses reasoning clinically, reflecting after Case 1 that “you need to have clinical reasoning to get through your exams” (Brianna, Interview 3, August 1, 2005). Brianna had not recognised the importance of the PBL process and “totally ignored what we’d done in PBL for the year… it wasn’t a very good way… it obviously didn’t work… I’d been doing heaps of work but I’d been doing the wrong type of work” (Brianna, Interview 2, August 23, 2004). Brianna had not understood that the course was integrated and that she needed to be able to apply and reason with the knowledge she was learning, not just make her primary focus being able to regurgitate learned facts.

Students who reflected upon the integrated course structure and assessment process recognised the emphasis on the importance of developing clinical reasoning. However, many students recognised that clinical reasoning was important. “It’s the most important thing because… if you’ve got a doctor with poor clinical reasoning… you’re either going to get a bad diagnosis or you’re not going to get a diagnosis” (Interview 42.1, August 4, 2005). Typically, students reported that “you can’t be a doctor without knowing” clinical reasoning (Interview 41.1, August 1, 2005) and that clinical reasoning “will really help you throughout your entire career as a doctor" (Chris, Interview 3, August 8, 2005). Where students differed was that good clinical reasoners understood what clinical reasoning was.

> *Clinical reasoning is… being able to come up with a clear picture of what's happening in this patient, being able to… hypothesise and order what situations are likely for this patient and what mechanisms and processes are occurring and… how to go about investigating them and how to go about treating them.*
> (Interview 33.2, August 17, 2005)

Good clinical reasoners prioritised developing this set of skills themselves, seeing "clinical reasoning… [as] the point of coming to Med School" (Interview 33.2, August 17, 2005). As Chris described:

> *Anybody can get an amount of experience and knowledge, and basically a computer could do that, but what differentiates a computer from… doctors is that doctors are actually using clinical reasoning… using the knowledge that they have and the experience that they have in a much more powerful way, I've got to say, than that of a computer.*
> (Chris, Interview 3, August 8, 2005)

In contrast to students such as Chris, weak clinical reasoners admitted to being ignorant about the definition of clinical reasoning: "I don't kind of understand what clinical reasoning is" (Interview 49.1, August 11, 2005). As one student reported: "I hadn't even really thought about what clinical reasoning is until I got asked to do this interview" (Interview 42.1, August 4, 2005). Weak students with little understanding of clinical reasoning had not recognised or even begun to reflect upon the importance of developing this set of skills.

In summary, students better at clinical reasoning had more insight into the fact that the integrated course structure existed and what this implied about the importance of clinical reasoning. Having an understanding of clinical reasoning, recognising its importance from the beginning of the course and making the development of this set of skills one of the primary aims of their medical education were things that distinguished the students who were good at clinical reasoning from those who were not. However, the course structure was not the only factor that stressed the importance of clinical reasoning and promoted its development. Individual components of the medical course also did this as they provided other forums where clinical reasoning was modelled for the students.

#### *7.3.1.2 PBL Tutorials and Clinical Skills Teaching Sessions*

Clinical reasoning was modelled both during Clinical Skills teaching sessions and PBL tutorials in the program. The examples of clinical reasoning given in these parts of the program aided the development of students' clinical reasoning ability in different ways.

For good clinical reasoners such as Alison and Chris, the development of clinical reasoning was promoted by being able to observe the modelling of clinical reasoning and participate in hospital tutorials and in clinical skills teaching sessions.

> *When we have clinical skills tutorials and there's actually a doctor teaching us how to do physical examinations… and a history… [asking] what you may or may not see… and what you should be thinking of, it sort of teaches how to reason through physical examination and… not only do you build your knowledge but also we are taught how to reason.*
> (Chris, Interview 3, August 8, 2005).

Students recognised that clinicians could help them in their understanding of the reasoning process. "The best thing they can do is just put us in with a clinician because… they're the people who do have that broad… experience" of clinical reasoning (Interview 33.2, August 17, 2005). Clinicians helped one good clinical reasoner to learn how to prioritise diagnostic hypotheses. "A clinician can be really great as a tutor because they… say "This… is more common, more likely and problematic in actual practice…". That's really important" (Interview 33.2, August 17, 2005).

Clinical Skills tutors critically questioned students' clinical reasoning during tutorials. This modelling of critical thinking as part of reasoning demonstrated to students that it was an important ability to develop in order to reason through a case. Brianna commented that "seeing how real doctors do it… really helps" (Brianna, Interview 3, August 1, 2005). Brianna went on to add:

> *This year being out in the hospital and having consultants ask "Why is this? Why is this? Why is this?"… you start to really quickly I think reason why it could be. You can't just – in PBL you can make a wayward statement; everyone can laugh it off but the consultants don't do that. So you've really got to think before and have good reasoning behind you before you open your mouth.*
> (Brianna, Interview 3, August 1, 2005).

Obviously, Brianna found it helpful for her clinical reasoning development to be questioned by tutors. Other students echoed her sentiments.

> *After I took my first history and [the tutor] asked me what was wrong… I realised I hadn't even thought about that, I'd just been asking the questions, giving not much thought otherwise to what could be causing it. So I think the questions asked by the tutor made me realise that that's what is meant to be happening.*
> (Interview 44.1, August 12, 2005).

Weak clinical reasoners failed to recognise that clinical reasoning was being modelled in Clinical Skills Teaching Sessions and the benefits this provided them with, whereas good clinical reasoners found the sessions invaluable for the development of their clinical reasoning skills.

However, clinical reasoning was not only modelled in clinical skills teaching sessions, but as most students recognised, it was also modelled by PBL tutors. Both good and weak clinical reasoners recognised and appreciated that tutors provided guidance about how to reason. Chris believed that tutors helped

> *by telling you… the… train of thought you should adopt. They teach you in a way that they have learned or gained through experience, so it's kind of like teaching clinical reasoning… PBL tutors will actually try and guide… to what is a good way of reasoning what is wrong with a patient and what strategies you should use to actually go about handling the case study.*
> (Chris, Interview 3, August 8, 2005)

This mentoring and facilitating role of the PBL tutor was an important part of helping students to understand the reasoning process they should adopt. "When you're trying to learn clinical reasoning you need a tutor – a mentor – who's going to teach you the general concept so that you can then actually get into it a lot more" (Interview 50.1, August 5, 2005). How a tutor may guide students was detailed by one student who stated:

> *My PBL tutor this semester is very good… he's basically saying that 'If you want the physical exam, you have to tell me what you think the problem would be and what you would expect to see and if it's not there, what does that mean and if it is there, what does that mean?'… which has been really, really good and… it's helped me to work out what I'm trying to do because previously when I haven't had any direction at all it's just kind of been like "Okay, we've got this history of this guy who's got a sore arm and it's swollen up a bit". Well, we can talk about the physiology of something swells up and then you are kind of at a loss of where to go from there.*
> (Interview 50.1, August 5, 2005)

Frank and Hannah, borderline clinical reasoners, also recognised that tutors "subtly point you in a direction, and that directs your clinical reasoning" (Frank, Interview 3, August 12, 2005). "The tutors and lecturers… provide a role model… they say… 'These are the steps that I'd go through to work through this' and… having that structure… [is] really helpful" (Hannah, Interview 3, August 5, 2005). Frank also found that the "personal feedback you get from tutors and also peers helps you in the sense that they tell you what you should improve at and it generally works" (Frank, Interview 3, August 12, 2005).

Based on these comments, it is evident that PBL tutors modelled clinical reasoning by critically questioning students' reasoning practices and that this was an important part of helping students to develop their own thinking processes. However, some weaker students relied on tutors to do the critical thinking for them, and did not develop this ability to think critically themselves. This may have limited the development of their clinical reasoning. One student found it difficult to work in PBL when his tutor did not place emphasis on testing hypotheses and forming mechanisms for the patient's symptoms and signs:

> *We've had a change in tutor and so it's really thrown the way that we learn in our group... Before it was more about… linking the signs and symptoms we were presented into a mechanism and understanding that information. But now… we sit there and talk about it… dot points under each… learning issue headings. And then… with the mechanism for that sign or symptom it just seems it doesn't really happen… We may have talked about it, but… it's not written anywhere, it's not in a mechanism.*
> (Interview 13.2, August 31, 2004).

PBL tutors modelling clinical reasoning can obviously have a large impact on the development of students' clinical reasoning. However, students also model clinical reasoning to each other as they participate in the tutorials. As a good clinical reasoner, Chris was encouraged to model clinical reasoning for his peers. Chris's tutors exhorted him to "think out loud a little more often… to help your group" as he had "very good reasoning skills" (Chris, PBL Tutor Report 1, May, 2004). The opportunity to be part of group learning was recognised to be valuable for helping to develop individual's clinical reasoning ability. As one student stated, "listening to other people has been the biggest thing that's helped me… mainly in my small groups, and comparing it with people in other groups and how they've reasoned out different things and gotten different conclusions" (Interview 53.1, August 1, 2005). Another student recognised that other group members modelling their clinical reasoning was an important resource as "the thinking process has been developed much more in the small groups because I sometimes try to think about the case by myself but it's very limited at home but if I work in groups people say things I haven't thought about so it's really good" (Interview 49.1, August 11, 2005). Hannah iterated that she "got a lot from hearing how people think and looking at the processes they follow and modelling my own on that" (Hannah, Interview 3, August 5, 2005).

Another example of the usefulness of peers modelling clinical reasoning skills was found in Frank's case study. In the latter half of first year medicine, borderline clinical reasoner Frank's group also helped him to develop his clinical reasoning by modelling how to generate hypotheses. Knowing that he would need to improve his ability to develop hypotheses after Case 1, Frank started "taking more notice of what's happening in the first session and other students in PBL group, how they [went] about hypothesising" (Frank, Interview 2, August 24, 2004). Frank thought that this helped him to improve his ability to generate hypotheses and his TACRR score for this skill did improve from 4/10 in the Case 1 Analysis to 9/10 in the Case 2 Analysis.

However, there were some negative aspects of having clinical reasoning modelled by peers in PBL groups. Some students were concerned that the development of their clinical reasoning could be led in the wrong direction, depending on "which group you're in, who you've got the example [of] to follow" (Brianna, Interview

3, August 1, 2005). This required intervention from the PBL tutor to facilitate correct clinical reasoning through constructive feedback.

In summary, reflecting upon the modelling of clinical reasoning in Clinical Skills teaching sessions and PBL tutorials had an impact on the development of students' own clinical reasoning. Tutors and peers providing examples of the process of using clinical reasoning skills as well as examples of how to think critically about reasoning was especially useful. However, some students commented that the usefulness of the modelling of clinical reasoning was very tutor- and peer-dependent.

##### *7.3.1.3 Section Summary*

Overall, the course structure emphasised the importance of developing clinical reasoning, and it was evident that tutors and peers also modelled clinical reasoning on a regular basis. However, it was the students, who reflected upon how the development of clinical reasoning was encouraged and modelled and who made developing this set of skills to be their overall aim, that tended to become better at clinical reasoning than others.

### 7.3.2 Practising Clinical Reasoning

Students may understand the importance of clinical reasoning, be in an environment where it is modelled and have the opportunity to observe the skills of clinical reasoning, but do not practice these skills, a task crucial for the development of clinical reasoning ability. Practising clinical reasoning and giving and receiving feedback about their performance allows students to recognise weaknesses in their clinical reasoning, to try to perfect these skills and abilities and to become more time efficient in their working through a case. There are many environments in which this clinical reasoning practice can take place. Students can practise clinical reasoning when alone as they learn information, by discussing their reasoning aloud in PBL tutorials and individually as they practise clinical skills during teaching sessions. The medical school examinations are another opportunity to practise clinical reasoning. As summarised by a student:

> *I'm quite aware that [clinical reasoning is] something I'm going to need to work on, so I think definitely the earlier you start the easier it's going to be, and then you finally get to the position where we're dealing with*

> *patients on our own… I think that’s what it’s all going to come down to… there are definitely going to be patients that come in and you’re really not sure what it is that they’re experiencing or what’s causing their problems, and you’re going to need to think about the symptoms and the underlying pathophysiology of it all, and you can work through it what it’s supposed to be.*
> (Interview 44.1, August 12, 2005).

Good clinical reasoners realised that clinical reasoning is developed with practice and that opportunities to do this were provided through the course: “the whole PBL process teaches you how to reason out for yourself. Every PBL case you do is actually more as a practice case on how to do clinical reasoning” (Chris, Interview 3, August 8, 2005). Another good clinical reasoner, Alison, confirmed that practising led to being more competent. Alison considered that in order to develop clinical reasoning it was important to “seize every opportunity… learn from your tutor in clinical skills, practise on other students when you have time and if you get the chance to see patients practise on them” (Alison, Interview 3, August 17, 2005).

However, weaker clinical reasoners were not sure that one could practise clinical reasoning: “I don’t know if it’s something that you can practise. I really couldn’t figure out a way to practise it properly I don't think” (Interview 53.1, August 1, 2005). The weaker clinical reasoners also did not recognise opportunities provided for practising clinical reasoning: “I don’t really think of practising clinical reasoning… there is nothing to practise on. They do have past exam papers where they do past cases but… there is no way for me to practise it so I just learn my notes” (Interview 41.1, August 1, 2005).

In summary, in order to develop clinical reasoning skills, students need to practise the process of clinical reasoning. Many opportunities are provided for students to do this in the course, and those who recognised and availed themselves of these opportunities became better clinical reasoners.

***7.3.2.1 Independent Practice***

Practising clinical reasoning outside of the course time was one way that better clinical reasoners differed from those who struggled to develop this set of skills. Practising clinical reasoning alone afforded a great opportunity to consolidate learnt knowledge. One student recognised that “if you took the time at home to…

figure out how what you were doing was applying to the case then you'd probably be able to develop more than if you just rote learn a whole bunch of notes and try and use them in your exams" (Interview 53.1, August 1, 2005). Part of reasoning individually involved learning how to construct arguments with this knowledge and as another student stated:

> *You need time to understand something to be able to go to your group and talk about it. I can't sit there and explain something to other people if I don't understand it myself so I find that very helpful because I have to have it straight in my own mind before I can tell other people what I know.*
> (Interview 48.1, August 3, 2005).

Students were required to engage all the skills of clinical reasoning and think critically in order to explain a patient's illness when doing individual study as they did not have others around them filling in the gaps left by their weaknesses. As outlined by one student:

> *Being in the group situation in PBL, it's easy just to rely on other members of the group to come up with the ideas, so I think my skills haven't improved as much as they possibly could have if I was placing more pressure on myself to come up with the ideas on my own… When it comes to doing the hard work of going through the presenting symptoms and working out what really would be their problem, it's very easy to let other group members sort it out, and I need to make an effort to work on those skills.*
> (Interview 44.1, August 12, 2005).

This sentiment was also expressed by another good clinical reasoner who found they needed "to do everything by myself again to actually make me develop my thinking processes" (Interview 49.1, August 11, 2005).

So practising clinical reasoning alone had many benefits: it helped to consolidate knowledge structures and also forced students to practise all the skills of clinical reasoning. However, practising clinical reasoning in a group also had advantages.

#### *7.3.2.2 PBL Tutorials*

Even if not diligently practising clinical reasoning when alone, all medical students were afforded the opportunity to do so in the PBL setting. Practising clinical reasoning with others gave students the opportunity to receive feedback.

Good clinical reasoners often reasoned aloud in class. Students who did not contribute to this process tended to be weaker clinical reasoners.

When asked what advice would be useful for new medical students who wanted to develop clinical reasoning, one student said: "practise in the PBL group… because in that setting you will get people… who will criticise you and… you will learn… You need to practise and you… definitely need to participate" (Interview 41.1, August 1, 2005). Another student echoed this viewpoint: "participate in PBL as much as possible, like, don't just sit there and let everyone else do the talking; really get involved, use your brain and think it through" (Interview 43.1, August 15, 2005). Participating in PBL was seen as important because "a small group… actually forces you to participate and… the discussion would definitely help clinical reasoning because you're… developing new ideas and actually exploring how different people think differently" (Chris, Interview 3, August 8, 2005). Participating in PBL tutorials was also seen as important as it was recognised that doing this would help to develop the processes students needed for their future professional practice:

> *PBL is really, really different from rote learning and it is really good because… when a patient comes to you, he is not going to come to you saying – I have this, I have that – and you are going to have to think for yourself. And I think it's really good, because even in the first year, I have already started to think like a doctor.*
> (Interview 27.1, August 26, 2004).

PBL helped clinical reasoners such as Brianna as it forced them to reason clinically, something they may not have done on their own. In Semester 1 of first year medicine, Brianna reflected that she often relied on other group members to help her with hypothesis explanation: "At the moment because it's just so hard to know exactly what to do… you sort of rely on the other people in your group doing something different… with the mechanisms" (Brianna, Interview 1, March 29, 2004). This assessment was supported by Brianna only scoring 4/10 for the logic of the mechanisms she detailed for Case 1, and 5/10 for their correctness and the way she supported her reasoning with information from the case. Tutors noticed this habit of Brianna's and encouraged her to "be more consistent in [her] participation in group discussion" and to also "continue to develop skill in re-evaluating hypotheses/differential diagnoses in a methodical manner", knowing that she was probably not proficient at hypothesis evaluation on her own (Brianna, PBL Tutor Report 4, October, 2004).

PBL was also helpful for Hannah who was reluctant to practise clinical reasoning during her individual study. PBL "just makes you practise it and I think… you just have to keep practising. It just doesn't come naturally for most people and it doesn't come naturally for me. It's just something that I have to keep working at" (Hannah, Interview 3, August 5, 2005). Hannah confessed that she was "not that motivated to do it at home and sometimes I find it just too difficult to do by myself. I prefer to have people to discuss it with" (Hannah, Interview 3, August 5, 2005). Hannah recognised that practising her clinical reasoning by discussing it with others was helpful as "it exposes your own weaknesses and also your strengths as well… you might think you have it when you're thinking it in your head but once you have to come to say it it's a lot harder… that's really helpful" (Hannah, Interview 3, August 5, 2005). However, it seems that Hannah did not put this theory into practice in her PBL tutorials. The eight PBL tutor reports Hannah received all included feedback that she needed to "increase her participation" (Hannah, PBL Tutor Report 1, April, 2004). This increased participation was needed so that Hannah could "apply [her] knowledge to discuss and test hypotheses" (Hannah, PBL Tutor Report 3, September, 2004) as well as "ask questions" to "re-evaluate the hypotheses" (Hannah, PBL Tutor Report 4, October, 2004). Hannah was reminded that "she might get more from the sessions if she became a bigger player" (Hannah, PBL Tutor Report 5, April, 2005) and that "as the reasoning aspect of PBL occurs in a largely informal manner, those that don't contribute to group discussion really don't get a chance to develop their own reasoning skills" (Hannah, PBL Tutor Report 7, September, 2005). Hannah's tutor was concerned that because she "wasn't very involved in these discussions… it is her reasoning skills that need significant improvement" (Hannah, PBL Tutor Report 7, September, 2005). Although Hannah recognised early in first year that she struggled to reason through cases, after two years of learning in this environment and being given the opportunity to practise this set of skills, she still had not progressed to being able to reason through cases independently.

Overall, PBL tutorials were a ready-made environment for developing clinical reasoning through practice and feedback, if students took up the opportunity they provided. However, although practising reasoning in PBL helped to develop clinical reasoning, clinical skills teaching sessions were also an important aid.

#### *7.3.2.3 Clinical Skills Sessions*

Clinical Skills tutorials afforded medical students another domain in which they could develop their clinical reasoning ability through practice. Clinical Skills teaching sessions tended to be more important for students who were weaker clinical reasoners, as they found the visual cues given by patients to be more engaging than PBL paper cases. These students enjoyed the way the Clinical Skills teaching sessions highlighted the necessity of developing clinical reasoning for becoming a doctor.

> *I think you could make an effort when you're in your clinical skills sessions, when we do history taking, make a point of not just taking the history but while you're taking it, you're thinking about what the symptoms that they're telling you could be leading to, and following up on each of those alleys that you might be considering in your mind…. A simulation of a real life consultation… although it's false, it sort of puts that pressure on you and gets you to be able to start thinking about being efficient in your reasoning and doing the things that you need to to get to the sort of differential diagnosis that you need.*
> (Interview 42.1, August 4, 2005).

Brianna and Hannah found that Clinical Skills motivated them to practise clinical reasoning as "putting symptoms and signs together… it's always really helpful to have a patient in front of you and be able to see it rather than just read it from a textbook" (Hannah, Interview 3, August 5, 2005). Similarly, Brianna believed the visual stimulus of a live patient was an excellent trigger for developing her clinical reasoning.

> *You take a history and you think to yourself "Okay, what could possibly be wrong with this person?" From a history [you] develop fairly firm ideas and then confirm that with your physical examination and investigations, which is what you do in PBL but it's just sort of harder I think in PBL because you're not actually seeing it; it's just written on paper… Clinical skills I think comes into that then because… when you see that in a patient it really sticks in your mind and then as you're taking the history like you think "Okay, now why could they be getting that?" and explore all the different ways they could be getting it.*

(Brianna, Interview 3, August 1, 2005).

Clinical Skills feedback also made Brianna realise that she should be reasoning as she was taking a patient's history: "You need to have good reasoning behind you to know why you're asking the questions instead of just learning questions off rote" (Brianna, Interview 3, August 1, 2005).

These Clinical Skills teaching sessions not only helped average clinical reasoners, they also helped better clinical reasoners. Chris claimed that "when you have tutorials in the hospitals… it helps to also reinforce whatever you've been taught" (Chris, Interview 3, August 8, 2005). The practice of clinical reasoning in Clinical Skills teaching sessions also helped good clinical reasoners to become more effective at working through a case. Chris maintained that

> *with practice and tutorials… and of course skills and increasing background knowledge we have, it gets better… the more patients you see and the more practise you get…it gets easier and it shortens the time you take to actually come up with a differential diagnosis then… most probable diagnosis.*
> (Chris, Interview 3, August 8, 2005).

Practising clinical reasoning during Clinical Skills tutorials augments the development of reasoning. For weaker clinical reasoners, the visual cue of real patients rather than paper cases motivated them to practise. For better reasoners, the practising of clinical reasoning with real patients in Clinical Skills teaching sessions stimulated them to become more effective in their reasoning. Another forum where students have the opportunity to practise reasoning is during examinations.

#### *7.3.2.4 Examinations*

By having to reason clinically during examinations, students are afforded the opportunity to demonstrate being able to reason under time pressure, an increasingly important part of clinical practice today. This clinical reasoning in examinations also forces each student to demonstrate all the reasoning skills as an individual, and provides a means of feedback to students about their reasoning ability.

Even for a good clinical reasoner such as Chris, although he thought he understood the process of clinical reasoning, he found that "under exam conditions to reproduce all that [required] quite a different thing" (Chris, Interview 2, August 26, 2004). Chris reflected that the most difficult part of the examination was knowing the significance of data points (Chris, Interview 2, August 26, 2004). Another student iterated that reasoning under examination conditions "helps you get the process… you do not have the group there to support, so it really builds your own personal skills" (Interview 43.1, August 15, 2005). The examination forced each individual to practise all the skills of reasoning.

Examinations also helped average clinical reasoner Brianna to learn to reason more effectively. Brianna believed practising clinical reasoning during the examinations increased "the speed that [she] can reason in" (Brianna, Interview 3, August 1, 2005). Another student found the examination valuable because

> *I found it was a good test just to see if I could actually apply what I'd learnt, especially when under pressure… I find that I know it and I understand it but I find it hard to express on paper so I always find exams a good way to make sure that I can actually express and make understood what I know, rather than just feeling I know it in my head but it's not quite organised enough to be able to explain it.*
> (Interview 48.1, August 3, 2005).

The examinations were "incentives to keep up with your work" and "revise the cases", as well as being useful for feedback (Interview 33.2, August 17, 2005). One student stated that "getting an… assessment on it makes you stop and think" about the ability to demonstrate each reasoning skill (Interview 53.1, August 1, 2005). So practising clinical reasoning during examinations also provided an opportunity for students to receive feedback on their ability in this area.

Developing the ability to reason clinically was promoted by practising doing it under examination conditions. It was useful for improving the ability to reason under pressure, forcing students to demonstrate that they were able individually to perform all the clinical reasoning skills and the examinations also provided students with feedback about areas of their clinical reasoning that could be improved.

#### *7.3.2.5 Section Summary*

There are many opportunities for students to practise clinical reasoning. They may do it as part of individual study, in PBL or clinical skills tutorials, and in their medical school examinations. The better clinical reasoners were those who availed themselves of every opportunity to practise and receive feedback on their clinical reasoning, whereas the weaker reasoners tended to be those students who chose not to participate in tutorials and who did not engage in developing their clinical reasoning independently.

### 7.3.3 Critical Thinking and Clinical Reasoning Ability

Initially it was hypothesized that critical thinking ability may have been a factor that impacted upon clinical reasoning development. Data about students' critical thinking ability was collected in the form of TACTT scores and from the case studies. There was little correlation between students' scores for critical thinking and their TACRR scores. However, extrapolation of data contained in the case studies revealed that students who practised thinking critically about their own arguments when alone or about others' reasoning when in groups tended to become better clinical reasoners.

#### *7.3.3.1 Statistical Correlations*

The relationship between clinical reasoning ability and critical thinking ability was investigated using total TACRR scores as a measure of clinical reasoning and TACTT, UMAT and TER scores as measures of critical thinking. Students' high school scores are made into a Tertiary Entrance Ranking (TER score) and consideration is given to this score when determining students' eligibility for university. Correlations between students' TACTT, UMAT and TER scores and their scores for clinical reasoning were included as students' scores on these intstruments were the best measures of their critical thinking ability available for this study. There was no statistically significant correlation between students' TACTT, UMAT or TER scores and any of their case analysis (TACRR) scores (Table 23). However, as there is little reported evidence that TACTT, UMAT and TER scores are valid measures of critical thinking ability (see Chapter Five), it is possible that a relationship between critical thinking ability and the development of clinical reasoning did exist but it was undetectable with these instruments.

Evidence from the case studies suggested that critical thinking ability does affect clinical reasoning development.

#### *7.3.3.2 Individual Study*

Students who thought critically about their reasoning, when studying individually, tended to develop better clinical reasoning skills than those who did not. These reasoners not only analysed and evaluated information and explained mechanistic arguments during private study, but also practised inference and self regulation on their own arguments as they did this analysis.

Table 23 - Correlations Between Students' Critical Thinking Ability According to TACTT, UMAT and TER Scores and their Clinical Reasoning Ability According to TACRR Scores for Case Analyses

| **Items Being Correlated** | | | **Pearson Correlation (r) Between Total TACRR Percentage Score and Critical Thinking Score** | **Significance** |
|---|---|---|---|---|
| **Critical Thinking Ability Indicator** | **Number of Subjects** | **Case Analysis Number** | | |
| TACTT February 2004 | 101 | 1 | -0.150 | 0.135 |
| | 101 | 2 | 0.097 | 0.332 |
| | 105 | 3 | 0.177 | 0.071 |
| | 105 | 4 | 0.128 | 0.681 |
| TACTT October 2004 | 89 | 1 | 0.077 | 0.472 |
| | 89 | 2 | 0.115 | 0.283 |
| | 92 | 3 | -0.001 | 0.993 |
| | 92 | 4 | -0.021 | 0.841 |
| TACTT February 2005 | 67 | 5 | 0.203 | 0.100 |
| | 67 | 6 | -0.158 | 0.201 |
| | 67 | 7 | 0.025 | 0.841 |
| TACTT October 2005 | 67 | 5 | 0.026 | 0.833 |
| | 67 | 6 | -0.053 | 0.671 |
| | 67 | 7 | -0.003 | 0.979 |
| TER | 74 | 1 | 0.196 | 0.095 |
| | 74 | 2 | 0.245 | 0.035 |
| UMAT | 70 | 1 | 0.113 | 0.350 |
| | 70 | 2 | 0.036 | 0.770 |

Alison identified early in the course that new information about a case meant she would have to use the critical thinking skills of analysis, evaluation and inference to reprioritise her hypotheses: she had to "think "What are all the possibilities?"… That whole differential diagnosis thing [of] each time we get new information,… changing the order – 'What's more likely?, Less likely?'" (Alison, Interview 1, May 19, 2004). This led to employing the critical thinking skill of self-regulation when Alison "managed to identify areas… which she feels they are doing well along with areas that could be improved" (Alison, PBL Tutor Report 1, April, 2004).

Thinking critically about their clinical reasoning during individual study prompted students to consider all the clinical reasoning skills in order to explain a patient's illness. Unlike PBL where the group may "pick you up on everything you don't know and… gaps in your reasoning and they test it all the time" (Interview 51.1, August 5, 2005), during individual study no other student could fill the gap left by one's reasoning weaknesses. Using her critical thinking skills during individual study helped to develop Alison's clinical reasoning ability. Alison's PBL tutor highlighted her skills of analysis, evaluation, stating that she had "the ability to think laterally, meaning that she often comes up with alternative hypotheses that may have otherwise gone without explanation… she… [would] further develop and/or refine hypotheses, as well as propose alternative… ones" (Alison, PBL Tutor Report 2, June 2004). Alison's tutor also noticed that she was skilled at inference as she "is very questioning in her approach… as to why… information is important and how it fits into the case" (Alison, PBL Tutor Report 1, April, 2004).

In contrast to good clinical reasoners, average and weak clinical reasoners tended not to think critically about their clinical reasoning when studying independently. One student stated that "if you're just studying by yourself, you don't often ask the difficult questions. It's usually just taken as fact that 'That causes that' and you just don't even think about [the fact that] there should be a couple of steps in there" (Brianna, Interview 3, August 1, 2005). Similarly, Hannah also found it difficult to analyse information critically when working alone: "At home… I just can't figure it out. I sit there and I read it and I read it and I can't figure out 'How is this relevant? What does it mean?'" (Hannah, Interview 3, August 5, 2005).

From these case studies it seemed that lacking a critical thinking disposition or critical thinking skills impacted upon a student's clinical reasoning development. Students who reported that they employed critical thinking skills when reasoning independently tended to become better at clinical reasoning than those who did not employ these skills.

#### *7.3.3.3 Tutors, Other Students and the Group*

From the case studies, better clinical reasoners tended to use their critical thinking skills in all situations, when alone or in a group, to criticise their own reasoning and that of other people. Critically thinking about arguments may aid the development of clinical reasoning. However, it seems that some students felt their clinical reasoning was also developed by having others do the critical thinking for them.

Chris claimed that his clinical reasoning developed due to critical thinking about arguments, "getting into active discussion with your peers", as well as "studying alone and having to reason to yourself" (Chris, Interview 3, August 8, 2005). Chris also stated that in a situation "where you'll really understand this concept but the whole group doesn't and you'll start to explain it to the group and the other ones will want to ask you questions which will question how well you know the concept. That in itself helps you to learn [reasoning]" (Chris, Interview 1, April 27, 2004). Students who critically thought about an argument, whether it was one of their own or someone else's, were the students whose clinical reasoning most tended to develop.

As students justify their arguments in the face of criticism, they can be made aware of misconceptions, illogical arguments or weaknesses in their reasoning. One student described this process, stating that the "bouncing ideas off other people… is really useful in terms of developing reasoning… [as] it forces you to clarify and reason… you have to have backup arguments for points you want to make" (Interview 44.1, August 12, 2005). After review, arguments can be reformulated and reasoning practised and corrected. As another student asserted, critical review "helps you to be able to change the way you think" and develop good clinical reasoning (Interview 42.1, August 4, 2005). Giving and receiving feedback in PBL involves critical thinking as "people… help to find faults with your reasoning and I think when you listen to somebody else's reasoning… [you] see where they've gone wrong", too (Interview 53.1, August 1, 2005). So one student's critical comments about an argument proposed by another student causes the second student to engage in critical thinking about their own reasoning. As explained by one student, "having that group there does mean that you talk about stuff and you actually try and logically reason stuff out as opposed to just reading it or not realising that you need to work something else out" (Interview 50.1, August 5, 2005). Feedback from the peers was seen as especially important as students do not "feel as threatened by them… because they're sort of approximately on the same level" (Brianna, Interview 3, August 1, 2005).

Chris was a group member who stimulated the development of his peers' clinical reasoning: "you ask questions constantly to other members of the class to clarify what they mean and add to their thinking as well as testing hypotheses in a systematic way…" (Chris, PBL Tutor Report 5, April, 2005). Chris was also praised by his tutor for being "the guide for the class with other student… asking you questions whenever they are stuck. You constantly explain any sticky points [and] test certain hypotheses" (Chris, PBL Tutor Report 5, April, 2005).

Brianna was motivated to develop her clinical reasoning after seeing others in the PBL group demonstrate critical thinking skills of analysis, evaluation and inference: "intelligent people in my group… review where we are from what we've learnt. 'Is that hypothesis likely or unlikely? Okay. So it is not likely. Now, why isn't it likely?'… I've been trying to do that more on a personal level" (Brianna, Interview 3, August 1, 2005).

However, students who relied on others to think critically about their arguments in PBL sessions found that there was then a temptation not to use their own critical thinking skills or develop their own clinical reasoning ability. Brianna found this, stating that:

> *sometimes I think being in a PBL group makes it really hard when you have someone that's probably a bit quicker at things than you are and you're still thinking through things in your mind and they've got it up there on the board and moving on to the next point and you're still trying to work it through your mind and so you don't actually have to reason.*

> *I’ve been in a couple of groups like that, so you end up not having to reason at all because you just rely on what they’re doing.*
> (Brianna, Interview 3, August 1, 2005)

This is when it becomes important for tutors to intervene so that all students have to use critical thinking skills and practise their reasoning. Brianna used to “absolutely hate” developing hypotheses but being in group with quieter students made a difference as “if you have people in your group that… know absolutely everything you never really want to say too much... but [now] I’m… more dominant than a lot of them, so I don’t mind it too much” (Brianna, Interview 3, August 1, 2005).

Tutors also helped the development of student clinical reasoning by challenging students’ arguments. One student stated that tutors did this “by questioning knowledge or any statements we make, and it forces you to think about why you’ve made that statement and what evidence you have to back it up” (Interview 44.1, August 12, 2005). Brianna echoed this sentiment, having found that feedback from clinical tutors was helpful as the students would “present the case back to him and [he’d] fire a series of questions off to us and we’d realise then how much we’d missed” (Brianna, Interview 3, August 1, 2005). Tutors, by “asking questions… making us consider things we might not otherwise consider… and giving us that… stimulus to go away and further reason as to what… we need to find out”, helped the development of our clinical reasoning (Interview 48.1, August 3, 2005).

Overall, critically thinking about arguments helped to develop students’ clinical reasoning ability. Students who were better at clinical reasoning were those who practised thinking critically about others’ reasoning in PBL sessions. However, someone else thinking critically about a student’s argument in a group setting also could affect the development of this student’s clinical reasoning ability, if the individual was then stimulated to think critically about their own arguments.

***7.3.3.4 Section Summary***

In summary, students’ critical thinking ability and a disposition to use these skills were factors that affected their clinical reasoning development. Students who thought critically about their own reasoning and that of others tended to become better clinical reasoners. The development of students' clinical reasoning may have been enhanced by others criticising their contributions in PBL sessions. However, those who found it difficult to interpret and question others' arguments in a group setting or manage self-regulation and critical thinking about their own reasoning when alone tended to become weak clinical reasoners.

### 7.3.4 Knowledge and Clinical Reasoning Ability

It is accepted that knowledge is necessary for clinical reasoning (Newble et al., 2000; Patel and Arocha, 2000). Data about students' knowledge level were collected from the case studies and in the form of scores for TACRR Question Nine, Examination A, Examination B and Examination C. There were significant positive correlations between students' knowledge level and their clinical reasoning ability. However, the elaboration of students' knowledge and their ability to apply it to clinical cases had more impact on their clinical reasoning development than their knowledge level alone.

#### *7.3.4.1 Statistical Correlations*

In order to examine the effect of knowledge on students' clinical reasoning ability, students' scores for TACRR Question Nine were subtracted from their total TACRR scores and sub-total TACRR percentage scores, the sum of the students' scores for all TACRR questions except Question Nine, divided by 90, were calculated for each student. These sub-total TACRR percentage scores were a measure of clinical reasoning ability that excluded a knowledge component. Students' sub-total TACRR percentage scores for case analyses (a measure of their clinical reasoning ability) were correlated with their scores for TACRR Question Nine, Examination A, Examination B and Examination C (measures of their knowledge level) to investigate how the type of knowledge a student has impacts upon clinical reasoning ability. The examinations were integrated and tested biomedical science knowledge in the format of multiple choice and short answer questions (Examination A), questions based on human prosections or histological slides (Examination B) and modified essay questions (Examination C). For each student cohort, there was a significant positive correlation between all measures of their knowledge level and their clinical reasoning ability as measured by this sub-total TACRR percentage score (Table 24). This was in line with previous reports that knowledge is necessary for clinical reasoning (see Chapter Two).

However, the significant correlations between students' examination scores and their sub-total TACRR scores were only small to medium ($r$ ranged from 0.245 to 0.410, $p < 0.01$), whereas the significant correlations between students' TACRR Question Nine scores and their sub-total TACRR scores were consistently large ($r$ ranged from 0.789 to 0.917, $p < 0.01$). This indicated that students' level of applicable knowledge had more impact on their clinical reasoning ability than simply their level of knowledge in general. Data extrapolated from the case studies provided further evidence and insight into why this might be the case.

#### *7.3.4.2 Knowledge Level*

Students at medical school aim to learn knowledge and knowledge is necessary for clinical reasoning. However, evidence from the case studies suggested that a student developing a sound knowledge base did not automatically ensure that they also developed the ability to reason. Students needed to develop the ability to apply their knowledge to cases in order for it to become useful for clinical reasoning.

Students recognised that it was important to have knowledge in order to be able to reason clinically. As one student said: "you do have to have knowledge… [to] do clinical reasoning" (Chris, Interview 3, August 8, 2005). Other students reiterated this by saying that "clinical reasoning is nothing without… medical knowledge" (Interview 41.1, August 1, 2005) and that a "knowledge base… allows you to differentiate between different things… that can help your clinical reasoning because you can… work out what's more likely" (Interview 42.1, August 4, 2005). Alison and Chris, both good clinical reasoners, demonstrated good knowledge levels through their examination scores in first and second year (see Table 17, section 6.4). In contrast, Brianna, an average clinical reasoner, demonstrated much lower examination scores for knowledge over the same period of time (see Table 17, section 6.4).

Table 24 - Correlations Between Students' Knowledge Level According to TACRR Question Nine, Examination A, Examination B and Examination C Scores and their Clinical Reasoning Ability According to Sub-Total TACRR Scores for Case Analyses

| **Items Being Correlated** | | **Number of Subjects** | **Pearson Correlation (r) Between Sub-Total TACRR Percentage Score and Measure of Knowledge** | **Significance** |
|---|---|---|---|---|
| **Measure of Knowledge** | **Case Analysis Number** | | | |
| Case 1 TACRR Question Nine | 1 | 112 | 0.881 | < 0.01 |
| Year 1, Semester 1, 2004 Examination A | 1 | 112 | 0.185 | > 0.05 |
| Year 1, Semester 1, 2004 Examination B | 1 | 112 | 0.096 | > 0.05 |
| Case 2 TACRR Question Nine | 2 | 112 | 0.917 | < 0.01 |
| Year 1, Semester 2, 2004 Examination A | 2 | 112 | 0.283 | < 0.01 |
| Year 1, Semester 2, 2004 Examination B | 2 | 112 | 0.237 | < 0.05 |
| Case 3 TACRR Question Nine | 3 | 112 | 0.909 | < 0.01 |
| Year 2, Semester 1, 2005 Examination A | 3 | 112 | 0.293 | < 0.01 |
| Year 2, Semester 1, 2005 Examination B | 3 | 112 | 0.297 | < 0.01 |
| Year 2, Semester 1, 2005 Examination C* | 3 | 112 | 0.384 | < 0.01 |
| Case 4 TACRR Question Nine | 4 | 112 | 0.901 | < 0.01 |
| Year 2, Semester 2, 2005 Examination A | 4 | 112 | 0.208 | < 0.05 |
| Year 2, Semester 2, 2005 Examination B | 4 | 112 | 0.245 | < 0.01 |
| Year 2, Semester 2, 2005 Examination C* | 4 | 112 | 0.277 | < 0.01 |
| Case 5 TACRR Question Nine | 5 | 113 | 0.789 | < 0.01 |
| Case 6 TACRR Question Nine | 6 | 113 | 0.906 | < 0.01 |
| Year 1, Semester 1, 2005 Examination A | 6 | 113 | 0.392 | < 0.01 |
| Year 1, Semester 1, 2005 Examination B | 6 | 113 | 0.410 | < 0.01 |
| Case 7 TACRR Question Nine | 7 | 113 | 0.915 | < 0.01 |
| Year 1, Semester 2, 2005 Examination A | 7 | 113 | 0.269 | < 0.01 |
| Year 1, Semester 2, 2005 Examination B | 7 | 113 | 0.370 | < 0.01 |

* Examination C scores were available for second year medical students only.

However, students simply having a good knowledge base did not guarantee that they would be able to reason clinically. Although according to Chris' first examination scores he had a good knowledge level, Chris performed poorly on his Case 1 Analysis as he did not apply his information to the case (he only achieved a TACRR knowledge score of 4/10 for this case analysis). According to their Examination A, B and C scores (see Table 17 section 6.4), Hannah and Frank also had a good knowledge level during first and second year medicine. However, as evidenced by their low TACRR knowledge scores, Hannah and Frank did not apply this knowledge to most case analyses, and overall they demonstrated only a borderline ability to reason clinically (see Tables 17 and 18 in section 6.4).

Hannah, Frank and Brianna did not tend to learn and store information they acquired in a way that made it easy for them to retrieve this knowledge or use it for reasoning through new cases.  Hannah spent "more time learning the information… to have that knowledge behind" her before she planned to practise "applying it to a clinical setting" (Hannah, Interview 3, August 5, 2005). This habit did not go unnoticed by Hannah's PBL tutor who commented that she needed to "try to apply… knowledge" rather than just learn unrelated facts (Hannah's PBL Tutor Report, September, 2004). Although according to her examination scores Hannah had a good knowledge level, she was not able to apply this knowledge in her case analyses and consequently scored poorly in the knowledge sections of most of her TACRR analyses (see Table 17 and 18, section 6.4 for knowledge scores).

Brianna found that in medicine the "depth and the vast, broad amount of knowledge was just really hard" to learn and her "concern with it… [was being] able to know it and cram it" (Brianna, Interview 2, August 23, 2004). Brianna stated that she did not learn knowledge by "apply [it] to the patient" cases (Brianna, Interview 1, March 29, 2004). Instead, Brianna went "straight to the objectives and figured that that was what they were going to test the exams on" and "totally ignored what we'd done in PBL" (Brianna, Interview 2, August 23, 2004).  Brianna found that this method "wasn't a very good way" because she found it "hard to grasp it all" and could not remember her knowledge or apply it to the examinations (Brianna, Interview 2, August 23, 2004).

Similar to Hannah and Brianna, Frank's tutor reported that he did not tend to apply what he was learning to cases (Frank, Tutor Report 3, September, 2004). Although Frank's examination knowledge level scores were adequate (see Table 17, section 6.4), Frank's tutor noticed that in PBL Frank was "hesitant and unsure about the knowledge he present[ed]" and sometimes had "less than a complete understanding of the material" (Frank, PBL Tutor Report 3, September, 2004). Not learning information in the context of a case may have also been a reason for Frank being unable to apply it in his Case 1 Analysis. Frank attributed his poor score for this analysis to his inability to remember what little knowledge he did know, saying that "it was hard with the gastro intestinal tract because… it was probably my least strong system" (Frank, Interview 2, August 24, 2004).

From the case studies, it appeared that Frank, Hannah and Brianna were not practising applying knowledge as they learned it, leading to an inability to apply it to case analyses even if they were able to demonstrate a good knowledge level in the other examinations. In contrast, Alison and Chris were able to demonstrate good knowledge levels in both their examinations and their case analyses.

Alison and Chris attributed their ability to use their knowledge in case analyses to having practised applying information as they were learning it. Chris commented that "there is a wealth of information in medicine, and the most important [thing is] to… gradually build the steps from a big picture to the small picture… instead of just researching the information and… not applying it properly" (Chris, Interview 3, August 8, 2005). He explained this further by saying that "anybody can get knowledge… but you get… "more adept at using the knowledge" if you "relate whatever you have learnt to the case, and try as much as you can to… incorporate it into a bigger picture" (Chris, Interview 3, August 8, 2005). Chris' tutor confirmed that he practised applying his knowledge, reporting that he would always "use his integrated knowledge base to explain the physiological processes responsible for the signs and symptoms of the case" (Chris, PBL Tutor Report 1, April, 2005). Similarly, Alison's tutor noted that she would often "utilize her knowledge well" in PBL (Alison, PBL Tutor Report 1, April, 2004). Alison commented that with "so much knowledge out there" it was important "to be able to link everything up" (Alison, Interview 3, August 18, 2005). Alison said that she achieved this by "applying how much [information] I have [so that it]… builds on and on [until she could see] every bit fitting into the bigger picture" (Alison, Interview 3, August 18, 2005). Alison stated that this method of learning and elaborating her knowledge meant that when she tried to remember information and apply it to reason through cases "it just all sort of comes together" (Alison, Interview 3, August 18, 2005). Consistently practising applying their knowledge to cases in PBL may have been responsible for Alison and Chris learning and remembering or elaborating their knowledge in such a way that it was retrievable and able to be used to reason through new cases, as evidenced by their good TACRR knowledge level scores (see Tables 17 and 18 in section 6.4). Other consequences of students applying knowledge as it was learned and the impact this had on the development of their clinical reasoning are further discussed in section 7.3.5.

#### *7.3.4.3 Section Summary*

In summary, further evidence that knowledge is necessary for clinical reasoning was provided by this study. However, the level of knowledge students could apply to cases had a larger correlation with their clinical reasoning ability than simply their knowledge level in general. The level of knowledge students could apply to case analyses was related to the accessibility of their knowledge base for reasoning and the extent to which they had practised applying knowledge to cases previously. Data from this study indicated that the manner in which students learned their knowledge impacted on how accessible and useful their knowledge could be for clinical reasoning.

### 7.3.5 Approach to Learning and Clinical Reasoning Ability

Another factor that affected the development of students' clinical reasoning in this study was their approach to learning knowledge. Data about students' approach to learning were collected from the case studies and in the form of R-SPQ-2F scores. Students who integrated knowledge and applied it as they learnt it found that this approach tended to help them to develop elaborated knowledge bases. The creation and use of their elaborated knowledge bases positively influenced the development of their clinical reasoning ability, as the information they knew could be retrieved and used to reason through new cases.

#### *7.3.5.1 Statistical Correlations*

Data about students' approach to learning were collected in the form of R-SPQ-2F scores. It was interesting to note that very few (*N* = 2), of the students in first year medicine had a surface approach to learning as measured by the Biggs' R-SPQ-2F, although case study data suggested that some students may have had a superficial approach. Perhaps students did not report their behaviours honestly in the R-SPQ-2F. As shown in Table 25, there was one small but statistically significant positive correlation (r = 0.218, *N* = 105, $p < 0.05$) between measures of students' approaches to learning and their clinical reasoning ability in this study, and that was between the students' approach to learning in February 2004 and their TACRR score for Case 2.

Less than fifty percent of students responded to the questionnaire in 2005, which may have skewed the results. However, as shown in Table 26, there was no statistically significant correlation between first year medical students' February and October 2005 approaches to learning and any of their case analysis scores.

Although no definitive conclusions could be drawn from the quantitative data about how approaches to learning may relate to clinical reasoning ability, insights were obtained from the case studies about the relationship between these entities.

Table 25 - Correlations Between 2004 Students' Approach to Learning and their Clinical Reasoning Ability According to TACRR Scores for Case Analyses

| **Items Being Correlated** | | | **Pearson Correlation (r) Between Total TACRR Percentage Score and R-SPQ-2F Approach to Learning** | **Significance** |
|---|---|---|---|---|
| **R-SPQ-2F Administration** | **Case Analysis Number** | **Number of Subjects** | | |
| February 2004 | 1 | 105 | 0.071 | 0.082 |
| February 2004 | 2 | 105 | 0.218 | 0.025 |
| February 2004 | 3 | 105 | -0.089 | 0.327 |
| February 2004 | 4 | 105 | 0.017 | 0.862 |
| October 2004 | 1 | 80 | 0.186 | 0.098 |
| October 2004 | 2 | 80 | 0.151 | 0.089 |
| October 2004 | 3 | 80 | 0.321 | 0.073 |
| October 2004 | 4 | 80 | 0.638 | 0.404 |

Table 26 - Correlations Between 2005 Students' Approach to Learning And Clinical Reasoning Ability According to TACRR Scores for Case Analyses

| Items Being Correlated | | | Pearson Correlation (r) Between Total TACRR Percentage Score and R-SPQ-2F Approach to Learning | Significance |
|---|---|---|---|---|
| **R-SPQ-2F Administration** | **Case Analysis Number** | **Number of Subjects** | | |
| February 2005 | 5 | 50 | 0.080 | 0.582 |
| February 2005 | 6 | 50 | -0.011 | 0.940 |
| February 2005 | 7 | 50 | 0.233 | 0.103 |
| October 2005 | 5 | 61 | 0.236 | 0.067 |
| October 2005 | 6 | 61 | 0.055 | 0.676 |
| October 2005 | 7 | 61 | 0.011 | 0.936 |

#### *7.3.5.2 Integrating Knowledge*

Reasoning clinically involves integrating knowledge from different disciplines to work through a clinical case. The medical curriculum was structured in order to promote the integration of knowledge, but some students did not recognise the course structure or use it as a template for their own learning. This impacted on the integration of these students' knowledge and ultimately the development of their clinical reasoning.

In Semester 1, Alison, a good clinical reasoner, integrated much of her learning as she stated that "it makes sense when you do that, and relate everything… It draws everything in together - … the whole "big picture" thing.… I think that's very useful" for clinical reasoning (Alison, Interview 1, May 19, 2004). The lack of mechanistic explanations in resources forced students to practise applying their knowledge and integrating it with the case at hand, as in order to explain the patient's symptoms they had to bring physiology, anatomy and pathology knowledge together. Alison was able to adapt. However, it is possible that this lack of mechanistic information, although a positive influence for better students, made it extremely difficult for weaker students to learn how to integrate their knowledge. For one student, it was "hard… to find a link between the books" and to have an "understanding of physiology and then… cross into pathology [to explain] the clinical signs and symptoms" (Interview 33.1, September 2, 2004).

Brianna was initially overwhelmed and did not integrate her learning at all. Brianna stated “I knew most of the lectures linked into the case we were doing but I never – it never occurred to me that maybe you could take the lecture information and integrate that into what you’re doing in the PBL group” (Brianna, Interview 3, August 1, 2005). In first year, Brianna found amalgamating information into mechanisms was a challenge: “It’s all related to the mechanism - getting the whole mechanism started and working things out, and having to juggle a few mechanisms at the same time… that’s the hard thing – knowing where everything fits” (Brianna, Interview 1, March 29, 2004). Brianna’s tutors also noticed this, commenting that her “ideas might not always come through in a logical manner” (Brianna, PBL Tutor Report 3, June, 2005). Brianna had trouble integrating the information she had available to her and this affected her clinical reasoning ability, as reflected by her inability to support her reasoning with clinical information (5/10).

Hannah, a borderline clinical reasoner, made the comment “I often found it difficult when I was doing personal research to continually make justifiable links, and in some cases even find relevant information…” (Hannah, PBL Journal, May 6, 2004). Hannah was not integrating her learning during the semester, and was left to cram it before examinations: “during the… semester… I’ll just try to understand overall rather than all of the detail” - “you have to know everything… you just get lost in all that information” (Hannah, Interview 2, August 30, 2004). This lack of learning detail continued over the next twelve months, as reflected in Hannah’s PBL tutor reports where she was encouraged to “go into more scientific detail in… mechanisms” late into her second year (Hannah’s PBL Tutor Report, September, 2005). It may be that this lack of integration of knowledge and learning detail made it difficult for Hannah to access her knowledge and use it to analyse Cases 2, 3 and 4, hence her poor scores for these cases.

So the integration of knowledge as students were learning it may have affected the development of their clinical reasoning. Having assimilated knowledge from different disciplines made it easier for students to analyse cases.

*7.3.5.3 Applying Knowledge*

Further investigation of students' approaches to learning revealed that being able to apply knowledge to a case as it was being learned was another factor that impacted on clinical reasoning development. Students who were better at clinical reasoning tended to have applied all the knowledge they were learning, mostly to PBL cases, as they were learning it. This approach of constant application of knowledge meant that students were able to have a "really good understanding of what [they were] learning" (Alison, Interview 3, August 17, 2005). As one student summarised, "medicine is all reasoning so you have to get used to doing your reading… and trying to put that together with what you're getting from a patient and… try to work that out" (Interview 50.1, August 5, 2005).

In order to develop clinical reasoning, the quantity of knowledge students knew was less important than being able to apply this knowledge to a case. Good clinical reasoners recognised this. For Alison, "if [she has] less time it will be more about just applying less information to the case", whereas with "more time it will be about learning more and then applying how much I have" (Alison, Interview 3, August 17, 2005). Alison's PBL tutor reports validated that she managed to "utilise her knowledge well", "present her information in the form of a mechanism" and that she would always "provide justification" for why the information was important and "related to the case under investigation" (Alison, PBL Tutor Report 1, April, 2004). However, similar to Alison, Chris also concluded that knowledge was not everything as "having lectures helps to build a foundation for a base of knowledge [but] I'm not too sure how it would actually help the actual reasoning process" (Chris, Interview 3, August 8, 2005). After his poor performance (46% for the Case 1 Analysis), Chris realised that he needed to learn how to apply his knowledge.

Chris's habit of applying knowledge as he learned it paid dividends in the marked improvement of his case analysis scores, and was particularly noted by his second year PBL tutor who stated that Chris has "excellent knowledge… [and] constantly [applies this] knowledge to the case" (Chris, PBL Tutor Report 5, April, 2005).

Most students recognised that in order to develop clinical reasoning they had to apply information they were learning to clinical cases. However, in contrast to good clinical reasoners, average clinical reasoners found applying their knowledge to the case at hand to be a challenge. As Brianna stated: “we go away and look up a disease [and] rattle off a whole lot of useless information about it. [But] the difficult thing at the moment is researching it and knowing what’s going to apply to the patient” (Brianna, Interview 1, March 29, 2004). Brianna reported that she had “a lot of information that I don’t really know how to use yet” (Brianna, Interview 3, August 1, 2005). It may have been this lack of ability to apply information that hindered Brianna from developing her reasoning further.

Even Frank, a borderline clinical reasoner, reported that “just rote learning [rather than] getting an… understanding and then applying it” was not helpful for the development of his clinical reasoning “[as] knowing a lot of stuff and not being able to apply it is completely useless” (Frank, Interview 3, August 12, 2005). However, instead of applying information as he learnt it, Frank spent much time just reading, thinking that “if you have a broader knowledge base, then all your clinical reasoning is going to be better than if you don’t know anything” (Frank, Interview 3, August 12, 2005). This was similar to the approach used by another borderline clinical reasoner: “when I do study something at the moment I treat it as if it’s some important bit of scientific knowledge that I must remember but I haven’t actually thought about applying it” (Interview 41.1, August 1, 2005). Frank’s lack of applying knowledge as he was learning it may have hindered the development of his clinical reasoning ability. Frank was memorising but not necessarily understanding or applying what he was learning and this may have hindered the development of his clinical reasoning.

Hannah, another borderline clinical reasoner, found that “when it comes down to actually analysing it and thinking” about information, she had difficulty completing this task (Hannah, Interview 3, August 5, 2005). Hannah knew that “just from reading” she would not “develop clinical reasoning too much, except for the fact that it gives you the background knowledge” (Hannah, Interview 3, August 5, 2005). Hannah pointed out that she needed to practise applying information to a case and creating a mechanism for her hypotheses: “the structuring of information into a mechanism… is something I have to continue to work on” (Hannah, PBL Journal, May 6, 2004). This lack of application of knowledge may have hampered the development of Hannah’s knowledge base as well as her clinical reasoning ability, contributing to her poor performances in Cases 2, 3 and 4.

Overall, students who applied knowledge tended to acquire integrated knowledge faster and retain it longer than those who did not. Applying knowledge as it was learned, rather than learning a large amount of information unrelated to cases, tended to have a positive impact on the development of students' clinical reasoning ability.

#### *7.3.5.4 Section Summary*

Extrapolation of the data in these case studies suggested that a student's approach to learning knowledge impacted upon the development of their clinical reasoning. Good clinical reasoners were not only marked by the fact that they integrated the knowledge they learned from different areas, but also by their application of this knowledge as they learned it. Their integration and application of information to cases as it was learned may have helped them to create elaborated knowledge bases. These elaborated knowledge bases could then be accessed and the information utilized to reason through new cases.

## 7.4 CHAPTER SUMMARY

Overall, the development of clinical reasoning is a complex process that may be influenced by many factors. The results presented in Chapter Seven have provided insight into how student clinical reasoning changes during the first two years of their course. Chapter Seven has also highlighted some factors that impact upon the development of students' clinical reasoning, in particular focusing on how critical thinking ability, knowledge level and approaches to learning may affect the development of this set of skills.

TACRR provides information about the development of clinical reasoning. In year one, students better at reasoning tended to have developed proficiency in all areas of clinical reasoning. However, by year two, differences in clinical reasoning ability performances on Case 3 and Case 4 analyses were limited to the skills of hypothesis generation and making useful learning issues. This suggested that these were the most difficult clinical reasoning skills for students to master.

From this study, five themes were extrapolated as having impacted upon student clinical reasoning development:

- reflecting upon the modelling of clinical reasoning,
- practising clinical reasoning,
- critical thinking about clinical reasoning,
- acquiring knowledge for clinical reasoning and
- the approach to learning for clinical reasoning

The importance of clinical reasoning was highlighted by the integrated course structure and assessment process. Students who were able to define clinical reasoning and recognise that the course structure promoted clinical reasoning realised that clinical reasoning was important and made developing this set of skills their ultimate aim. These students became good clinical reasoners. Clinical reasoning was also modelled by tutors and peers in PBL tutorials and Clinical Skills teaching sessions and for those students who recognised this modelling, they were able to learn from these examples about the skills involved in clinical reasoning.

Practising clinical reasoning also emerged as a factor that was important for the development of clinical reasoning. Practising clinical reasoning alone, in PBL tutorials, in Clinical Skills Teaching Sessions and in examinations allowed students to test the logic of their arguments, recognise weaknesses in their clinical reasoning and improve it, as well as be more time efficient in working through a case. The better clinical reasoners were students who had availed themselves of every opportunity to practise clinical reasoning, whereas the weaker reasoners tended to be those students who chose not to participate in tutorials and who did not engage in clinical reasoning when alone.

Critically thinking about arguments was also deemed to be a factor that affected the development of students' clinical reasoning. Students who practised thinking critically about their reasoning when alone and in groups, and who critically examined the clinical reasoning of other classmates during PBL tutorials, tended to become good clinical reasoners. Students' development of clinical reasoning may also have been enhanced by other group members criticising their clinical reasoning during PBL.

This study provided further evidence that knowledge is necessary for clinical reasoning. However, students' knowledge level scores according to their examinations had smaller correlations with their clinical reasoning ability than the level of knowledge they were able demonstrate through case analyses. Data from this study indicated that the method students used to learn their knowledge impacted on how they were able to use this knowledge for clinical reasoning.

Lastly, students' approaches to learning impacted on their clinical reasoning development. Students who integrated and applied their knowledge to cases as they were learning it tended to find it easier to use this knowledge for clinical reasoning and were better at developing this set of skills.

# CHAPTER EIGHT - DISCUSSION AND CONCLUSIONS

## 8.1 AN OVERVIEW OF THE CHAPTER

This chapter reviews the results of the study in relation to each research question. The limitations of the study and recommendations arising from it for curriculum design, for teaching methologies and for further research are also considered.

## 8.2 DISCUSSION OF EACH RESEARCH QUESTION

### 8.2.1 How Can Clinical Reasoning Ability Be Measured?

As no instrument with which to measure the proposed clinical reasoning model existed, part of this present study involved developing an instrument to measure this entity. Chapter Four described the design, development and implementation of TACRR. This instrument underwent rigorous peer review for validation and had high internal consistency (Cronbach alpha coefficient 0.94), inter-rater reliability ($r$ = 0.84, $p<0.05$) and intra-rater reliability ($r$ = 0.81, $p<0.01$). The development of TACRR enabled the measurement of students' clinical reasoning ability for this study. Data from the case studies in Chapter Six provided further evidence for the validity of TACRR. Close examination of the students' case analyses yielded extrapolations about their clinical reasoning ability that were consistent with the students' TACRR scores of clinical reasoning ability. As explained in section 4.2, although making learning issues can be considered a skill separate to clinical reasoning, this skill was assessed as part of TACRR (Question Eight). Making learning issues was considered to be an integral part of students developing applicable knowledge bases that they could then use to reason clinically, and as such assessing students' skills in this area was deemed to be important for developing an understanding of their clinical reasoning development.

*The design, trial, implementation and analysis of TACRR through this study has provided evidence that the process of clinical reasoning can be measured through this instrument.*

### 8.2.2 How Do Students' Clinical Reasoning Abilities Change As They Progress Through The Program?

Using TACRR case analysis scores it was possible to develop a clearer understanding of the development of students' clinical reasoning ability over the first two years of their medical program. Students were split into three groups (I, II and III) according to whether their clinical reasoning had improved, not changed significantly or worsened between their Case 1 and Case 2 Analysis or their Case 3 and 4 Analysis, respectively. First year Group I, II and III students showed significant differences in clinical reasoning ability between their first and second attempt at a case analysis on all individual questions and sections of TACRR (see section 7.2, Tables 21 and 22). This suggested that initially better clinical reasoners developed superior reasoning ability in all the areas tested by TACRR concurrently.

In second year, better students demonstrated superior scores for some measures of overall clinical reasoning ability (significant differences arose between Groups I, II and III's scores for their overall approach to the case (question ten) and their total TACRR scores). However, there were significant differences in development between groups only in appropriate hypothesis generation and making useful learning issues.

These results were consistent with the analysis of the evidence from the case studies. The better clinical reasoners, Alison and Chris, developed a superior ability to demonstrate most of the criteria of clinical reasoning. However, it became apparent in second year that students weaker at clinical reasoning such as Brianna, Frank and Hannah found it increasingly difficult to generate hypotheses and make useful learning issues. These students' clinical reasoning ability did not develop over time.

*The evidence from this study suggests that students' clinical reasoning ability may develop over time through the program, but that this is not always the case. The criteria most difficult for students to develop were the ability to generate hypotheses and make useful learning issues. The relationship between the skill of making learning issues and clinical reasoning ability has not been clearly defined.*

### 8.2.3 What Factors Influence The Development Of Students' Clinical Reasoning Ability?

The case studies gave further insight into factors that influenced students' clinical reasoning development. From Chapters Six and Seven, students who were able to define clinical reasoning and recognise that the course structure promoted the development of this set of skills realised that clinical reasoning was important and made developing this set of skills their ultimate aim. These students became adept clinical reasoners. Clinical reasoning was modelled by tutors and peers in PBL tutorials and Clinical Skills Teaching Sessions and students who recognised this modelling learned from these examples about the skills involved in clinical reasoning. Students who did not recognize the modelling of clinical reasoning tended to be weaker at demonstrating this set of skills.

Evidence reported in Chapters Six and Seven also indicated that practising clinical reasoning was a factor that impacted on students developing this set of skills. The better clinical reasoners were students who had availed themselves of every opportunity to practise clinical reasoning, such as when alone, in PBL tutorials, during Clinical Skills Teaching Sessions or when in examinations. Weaker clinical reasoners tended to be those students who were either not able to, or chose not to, practise reasoning either when alone or in class.

*Five factors that influence the development of clinical reasoning were identified through this study, namely (1) reflecting upon the modelling of clinical reasoning, (2) practising clinical reasoning, (3) critical thinking about clinical reasoning, (4) acquiring knowledge for clinical reasoning and (5) the approach to learning for clinical reasoning. The first two factors have been discussed in this section and the last three will be discussed in Sections 8.2.5, 8.2.6 and 8.2.7, respectively.*

### 8.2.4 How Can Students' Critical Thinking Ability Be Measured?

One aim of this study was to establish how critical thinking ability impacted on the development of clinical reasoning ability. Given the lack of an available and appropriate critical thinking instrument for this study, a critical thinking instrument (TACTT) was developed for the purpose of this investigation.

The development of TACTT included an extensive peer review validation process (see Chapter Five). TACTT did not have adequate internal consistency as the Cronbach Alpha coefficients ranged from 0.23 to 0.67 (see Tables 10 and 11 in Chapter Five) when it was tested on first year students. The range of TACTT scores for these cohorts also did not follow a normal distribution and the Kolmogorov-Smirnov statistic significance was less than 0.05 for each cohort (see Table 11), suggesting violation of the assumption of normality.

*The development of an instrument with the necessary psychometric properties to measure undergraduate medical student critical thinking ability was not achieved through this study.*

### 8.2.5 How Do Students' Critical Thinking Abilities Influence Student Clinical Reasoning?

It was hypothesized that critical thinking ability may have been a factor that impacted upon clinical reasoning development. Although TACTT had poor psychometric properties, it was the best available tool for measuring the students' critical thinking ability. Therefore, as explained in Chapters Five and Six, data about students' critical thinking ability were collected in the form of TACTT scores and the results suggested that critical thinking ability did not affect clinical reasoning development. However, given that there was little evidence that TACTT scores are valid measures of critical thinking ability, it is possible that a relationship between critical thinking ability and the development of clinical reasoning did exist but it was undetectable with this instrument.

*Evidence from the case studies in Chapters Six and Seven suggested that students who reported attempting to think critically about their own clinical reasoning or that of others were found to have improved most in their clinical reasoning development. The clinical reasoning development of students who reported that they did not use critical thinking skills when alone or in class may have been enhanced by the influence of others who critiqued their set of skills, but these students reported that they still tended to struggle to develop the ability to reason well when alone.*

### 8.2.6 How Do Students' Knowledge Bases Influence Their Clinical Reasoning?

Data about students' knowledge level were collected from the case studies and in the form of examination and TACRR Question 9 (knowledge) scores. For each cohort studied, there was a significant positive correlation between all measures of students' knowledge level and their clinical reasoning ability as measured by TACRR. However, the correlations between students' clinical reasoning ability and their general knowledge level (as measured by examination scores) were smaller than the correlations between their clinical reasoning ability and their level of applicable knowledge (as measured by their TACRR knowledge scores).

*Further evidence that knowledge is necessary for clinical reasoning was provided by this study and was reported in Chapters Six and Seven. Extrapolation of the data from the case studies also suggested that students' ability to apply knowledge had a larger impact on the development of their clinical reasoning ability than their level of knowledge alone. This is further discussed in section 8.2.7.*

### 8.2.7 How Do Students' Approaches to Learning Influence Their Clinical Reasoning?

It was also hypothesized that a student's approach to learning may have been a factor that impacted upon clinical reasoning development. Data about students' approach to learning were collected from the case studies and in the form of R-SPQ-2F scores. As reported in Chapter Seven, for the 2004 first year medical student cohort, there was a small but statistically significant positive correlation between the students' approach to learning in February 2004 and their score for Case 2. However, this result was not replicable with the 2005 first year medical student cohort and their scores for Cases 5, 6 or 7. The fact that less than fifty percent of students responded to the questionnaire in 2005 would have affected the possibility of being able to replicate the results obtained with the 2004 cohort. Very few ($N$ = 2), of the students indicated that they had a surface approach to learning as measured by the Biggs' R-SPQ-2F. This may have skewed the results such that a relationship between students' approaches to learning and their development of clinical reasoning ability did exist but it was undetectable when using the R-SPQ-2F.

*Evidence from the case studies provided some insight into how students' approaches to learning affected their clinical reasoning. It was a more complex issue than whether the student reported being a deep or a surface learner. As described in Chapter Six, it was found that students who integrated and applied knowledge to cases as they learned it developed elaborated knowledge bases and tended to become better clinical reasoners. Students who had elaborated knowledge bases retained their knowledge longer, could retrieve it and apply it to new cases better, and were able to acquire new integrated knowledge faster than others who did not.*

## 8.3 LIMITATIONS OF THIS STUDY

This study has provided insight into the development of undergraduate students' clinical reasoning. However, there were some limitations of this research. Students were only studied for two years, given the time constraints on this Doctor of Philosophy project. Changes in students' clinical reasoning ability may have been more measurable and informative over a longer period of time. Also, the students in this study were in first and second year medicine. It may be that clinical reasoning develops much more markedly in students in the latter years of the medical program, where they are predominantly in the clinical setting and faced with reasoning through real patients' cases in real time.

This study provided evidence that TACRR is a valid tool for measuring clinical reasoning, but it generates a score of clinical reasoning ability based on a student's performance on just one case. This performance may be quite dependent on knowledge in the particular area of the case, which may limit TACRR's sensitivity. However, TACRR proved to be valid when used to analyse four different cases. The content of these cases was not controlled, as they were part of students' regular examinations. The validity of TACRR would be enhanced by testing it with more experienced clinical reasoners, with a larger cohort of subjects and in an institution other than one in which this study was conducted.

As no affordable and valid critical thinking tests existed, TACTT was designed to measure the critical thinking ability of subjects in this research. Subjects' TACTT scores were also used to help to categorise students into groups for the wider study. The fact that TACTT did not prove to be valid as a measure of critical thinking was not established until late in the study, after TACTT data had already been used and incorporated into the research. For this reason, TACTT data has still been reported in this thesis. However, given TACTT's lack of validity, the quantitative data results about the relationship between clinical reasoning and critical thinking can only be considered as speculative.

Using the R-SPQ-2F for this study was useful to measure students' approaches to learning as the questionnaire was valid, took little time, was easy to administer and it was inexpensive. However, perhaps due to the selection process at medical school catering for deep learners or students perceiving that it was seen as socially desirable in an academic world to be a deep learner, very few students were categorised as surface learners. This skewing of results meant that no quantitative data results about the relationship between clinical reasoning and approaches to learning as measured by the R-SPQ-2F were generated.

Other information about approaches to learning was generated using qualitative methodologies. The trustworthiness of qualitative research (its consistency, truth value and transferability) is directly related to the credibility of the investigator and the rigor of the research methods used to conduct it. Only five case studies were reported as part of this thesis, so the transferability of the results may be limited. However, data collection was continued until the point of redundancy was reached. The selection of the case studies was based on a process that involved categorizing students according to their scores on TACTT and the R-SPQ-2F. Every effort was made to increase the consistency and truth value of this study by detailing the researcher's position, assumptions and biases, detailing an audit trail of the study that included triangulation, member checks and peer examination of results and to increase the transferability of the study by providing rich, thick description.

## 8.4 RECOMMENDATIONS FOR MEDICAL CURRICULUM DESIGN, TEACHING AND ASSESSMENT

The insights into the development of student clinical reasoning provided by this study have important implications for curriculum design, teaching and assessment in medical schools. As clinical reasoning is a component of clinical competence it is imperative that students develop this set of skills.

Recommendations based on this study are as follows:

1. Curriculum planners need to identify the reasoning that they expect students to demonstrate and ensure that the learning and assessment practices are consistent with this expectation.
2. The fact that a program seeks to focus on developing students' clinical reasoning needs to be carefully articulated in program design, teaching and assessment. This may then enable students to understand the importance of mastering this set of skills and encourage them to personally to focus on developing their clinical reasoning.
3. Modelling of clinical reasoning is important to help students to understand the reasoning process. This modelling should be explicit and graduated to enable students to understand the process. It should be integrated into programs and included in PBL, clinical, and small and large group teaching sessions.
4. Tutors have an important role in developing students' reasoning abilities. Tutors need to be taught to model the reasoning process for students and to encourage and critique students' clinical reasoning performance. Further training of tutors in order that they can develop this expertise may be necessary.
5. Students need to be given opportunities to practise clinical reasoning and receive feedback on their clinical reasoning performance. Online cases could be developed to demonstrate to students how to reason clinically and to demonstrate how to practise the skills required. A self assessment package that is modelled on TACRR could be developed to enable students to assess their level of performance. Teaching workshops could be developed for students who have difficulty with a particular element of clinical reasoning (e.g. hypothesis generation, or developing learning issues).
6. TACRR is a valid, reliable instrument that can be used to provide formative information to students' about their clinical reasoning ability.

7. Collaborating with other medical schools about the measurement of clinical reasoning may lead to TACRR being used in other environments, enabling further validation and modification of the instrument as necessary.
8. Development of students' abilities to think critically should be integral to programs. This critical thinking ability could be developed through a variety of educational activities and would not necessarily need to be based on clinical cases in the first instance.
9. Tutors abilities to model critical thinking for students and to encourage students to think critically about their reasoning need to be developed.
10. In curriculum design, teaching and assessment, greater emphasis needs to be placed on encouraging a deep approach to learning and developing students' abilities to integrate knowledge so that they can apply information from their elaborated knowledge bases to their clinical reasoning.

## 8.5 RECOMMENDATIONS FOR FURTHER RESEARCH

This work provided insight into the development of the complex process of clinical reasoning and the factors that determine why students vary in their ability to reason clinically. Further research is necessary to explore the validity of the case study results. TACRR was demonstrated as being useful as a formative tool to investigate the development of clinical reasoning, but further validation of this instrument is needed. Using the instrument with later year students may provide insight into changes in their reasoning ability over time during the course. Additional studies are also necessary to link student performance on this clinical reasoning instrument with other measurements of clinical performance as they progress through medical school. Critical thinking ability, knowledge level and approaches to learning have been demonstrated as factors that affect the development of clinical reasoning, but further research needs to be done to explore how and to what extent these factors are important. This requires the creation of more sensitive measures of critical thinking and approaches to learning than TACTT and the R-SPQ-2F.

Hypothesis generation and making learning issues have been highlighted in this study as skills that students find difficult to develop. Given that hypothesis generation is integral to students becoming proficient doctors, further analysis of this skill and investigation of why it is difficult for students to develop, including how students can increase their abilities in this area, is warranted. Exactly how making learning issues is related to clinical reasoning and analysis of how to help students to learn this skill is also a topic requiring further study. As clinical reasoning is such an important component of clinical competence, much more research needs to be conducted to explore how clinical reasoning develops during difference stages of medical education and how best to enhance the development of this important set of skills.

# APPENDIX A - DOCUMENTS FOR INFORMED CONSENT

THE UNIVERSITY OF ADELAIDE AUSTRALIA

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INFORMATION SHEET REGARDING THE RESEARCH PROJECT INVESTIGATING THE DEVELOPMENT OF STUDENTS' CLINICAL REASONING IN AN UNDERGRADUATE MEDICAL CURRICULUM

This information sheet explains the purpose and nature of the study called ***"The development of students' clinical reasoning in an undergraduate medical curriculum"*** and what is involved if you choose to participate in this project.

This research is being conducted by Dr. Kirsty Anderson as part of her Masters of Medical Science research, and is funded by the Faculty of Health Sciences Divisional Scholarship. The purpose of this study is to better understand the development of clinical reasoning in medical students, and how approaches to learning and critical thinking ability impact upon this. By understanding how a precursor for clinical competence such as clinical reasoning develops, this study will provide useful information for how best to shape the curriculum to enhance medical students' clinical reasoning and ultimately the ability of future doctors.

This study will be conducted over 2 years at the University of Adelaide Medical School. It will involve the 2004 first year medical student cohort over this period of time. As part of this cohort, you are being invited to fill out questionnaires and then some randomly selected students will be invited for an interview.

Participants in this project will be invited to fill out questionnaires during Orientation Week/Week 1, Semester 1 in 2004 and in mid-year 2005. These questionnaires will enable Kirsty to rank students' approaches to learning and critical thinking ability. Students scores on the *Undergraduate Medicine and Health Sciences Admission Test* (*UMAT*) or *Personal Qualitities Assessment Test* will be correlated with their score on the critical thinking questionnaire, to ensure that the questionnaire is valid. Up to 20 randomly selected students who have filled out the questionnaires will be invited to participate in a taped interview lasting up to one hour with Kirsty. This interview will be conducted at a mutually convenient time and place to further explore your approach to learning and critical thinking ability. This interview will be taped, de-identified and transcribed by a contractor. The interview tapes will have codes on them so that the transcriber will not know the identities of the students involved. All students interviewed will be given a copy of their own interview transcript and allowed to amend it before approving it for analysis. Any amendments suggested by the student involved will be made to the transcripts before they are analysed. In addition, after you have completed your examinations during years 1 and 2 of the medical course, some papers will be reviewed and ranked by Kirsty for evidence of your clinical reasoning ability. Up to 20 randomly selected students who have done the examinations will be invited to participate in a taped interview lasting up to one hour with Kirsty. This interview will be conducted at a mutually convenient time and place to further explore your clinical reasoning. This interview will be taped, de-identified and transcribed by a contractor. The interview tapes will have codes on them so that the transcriber will not know the identities of the students involved. All students interviewed will be given a copy of their own interview transcript and allowed to amend it before approving it for analysis. Any amendments suggested by the student involved will be made to the transcripts before they are analysed. It must be emphasised that **participating in this project has no impact upon your assessment during or progression through the medical course**. Your decision to participate or not to participate and the details of your participation in this project will be confidential, including from academic staff. In addition, Kirsty normally has some assessment responsibilities within the Medical Education Unit. However, for the duration of your medical education at the University of Adelaide, Kirsty will have **no involvement in assessing any students who are in first year medicine in 2004 or 2005**.

No harm will come to you as a result of your choice to participate or not to participate in this project. You can decline to be involved in a part of or withdraw completely from the project at any time without prejudice. All information gathered during this project will remain confidential: results made public will be anonymous. Participants' identities will be concealed via identity coding and de-identification of data, and there will be secure storage of research records. Students will be randomly selected for interviewing and are under no compulsion to participate.

Participating in this project is voluntary and participants must be fully informed, therefore it is important that you understand all the information provided. You are welcome to have a friend look over the project information sheet with you before making a decision, and please do not hesitate to contact me for further information (see contact details below). You can also contact the project supervisor or the Human Research Ethics Committee as indicated on the sheet provided. All participants should keep the information sheet. Both copies of the consent form should be signed and one copy kept by you. Thank you for taking the time to read this material – I look forward to working with you!

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THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

CONSENT FORM FOR QUESTIONNAIRES AND INTERVIEWS RELATED TO
the development of students' clinical reasoning in an undergraduate medical curriculum

1. I, ……………………………………………………………… *(please print name)*

consent to take part in the research project entitled: The development of students' clinical reasoning in an undergraduate medical curriculum.

2. I acknowledge that I have read the attached Information Sheet entitled: The development of students' clinical reasoning in an undergraduate medical curriculum.

3. I consent to my UMAT or PQAT scores to being used in order to validate the critical thinking questionnaire being used by the researcher.

4. I understand that any interviews that occur during this project will be taped, de-identified and transcribed by a contractor, that the interview tapes will have codes on them so that the transcriber will not know the identities of the students involved, that all students interviewed will be given a copy of their own interview transcript and allowed to amend it before approving it for analysis and that any amendments suggested by the student involved will be made to the transcripts before they are analysed.

5. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

6. Although I understand that the purpose of this research project is ultimately to improve the quality of medical education, it has also been explained that my involvement may not be of any benefit to me.

7. I have been given the opportunity to have a friend present while the project was explained to me.

8. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

9. I understand that I am free to withdraw from the project at any time and that this will not affect my assessment during or progression through medical school in any way.

10. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

……………………………………………………………………………………………...
(signature) (date)

I certify that I have described the nature of the project to the student and consider that she/he understands it and freely consents to take part.

…………………………………………………………………………………………...
(Researcher's signature) (date)

THE UNIVERSITY OF ADELAIDE
HUMAN RESEARCH ETHICS COMMITTEE

Document for people who are subjects in a research project

CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The Human Research Ethics Committee is obliged to monitor approved research projects. In conjunction with other forms of monitoring it is necessary to provide an independent and confidential reporting mechanism to assure quality assurance of the institutional ethics committee system. This is done by providing research subjects with an additional avenue for raising concerns regarding the conduct of any research in which they are involved.

The following study has been reviewed and approved by the University of Adelaide Human Research Ethics Committee:

Project title: The development of students' clinical reasoning in an undergraduate medical curriculum.

1. If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the project co-ordinator:

*Name:* Dr. Ray Peterson
*Telephone:* **08 8303 6063**

2. If you wish to discuss with an independent person matters related to
   - making a complaint, or
   - raising concerns on the conduct of the project, or
   - the University policy on research involving human subjects, or
   - your rights as a participant

contact the Human Research Ethics Committee's Secretary on phone (08) 8303 6028

# APPENDIX B - A MEASURE OF APPROACHES TO LEARNING

## R-SPQ-2F
## THE REVISED TWO FACTOR STUDY PROCESS QUESTIONNAIRE

Instructions

This questionnaire has a number of questions about your attitudes towards your studies and your usual way of studying.

There is no right way of studying. It depends on what suits your own style and the course you are studying. It is accordingly important that you answer each question as honestly as you can. If you think your answer to a question would depend upon the subject being studied, give the answer(s) that would apply to the subject most important to you.

Please circle the appropriate letter alongside the question number on the answer sheet. The letters alongside each number stand for the following response:

**A** - this item is ***never*** or ***only rarely*** true of me
**B** - this item is ***sometimes*** true of me
**C** - this item is true of me ***about half the time***
**D** - this item is ***frequently*** true of me
**E** - this item is ***always*** or ***almost always*** true of me

Please choose the *one* most appropriate response to each question. Circle the most appropriate letter on the answer sheet that best fits your immediate reaction. Do not spend a long time on each item: your first response is probably the best one. Please answer each item. Do not worry about projecting a good image. Your answers are **CONFIDENTIAL**. Thank you for your cooperation.


From the British Journal of Educational Psychology (2001), 71, 133-149

| Circle the letter that best fits your immediate reaction. | never or only rarely | sometimes | about half the time | frequently | always or almost always |
|---|---|---|---|---|---|
| 1. I find that at times studying gives me a feeling of deep personal satisfaction. | A | B | C | D | E |
| 2. I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied. | A | B | C | D | E |
| 3. My aim is to pass this course while doing as little work as possible. | A | B | C | D | E |
| 4. I only study seriously what's given out in class or in the course guidelines. | A | B | C | D | E |
| 5. I feel that virtually any topic can be highly interesting once I get into it. | A | B | C | D | E |
| 6. I find most new topics interesting and often spend extra time trying to obtain more information about them. | A | B | C | D | E |
| 7. I do not find my course very interesting so I keep my work to the minimum. | A | B | C | D | E |
| 8. I learn some things by rote, going over and over them until I know them by heart even if I do not understand them. | A | B | C | D | E |
| 9. I find that studying academic topics can at times be as exciting as a good novel or a movie. | A | B | C | D | E |
| 10. I test myself on important topics until I understand them completely. | A | B | C | D | E |


From the British Journal of Educational Psychology (2001), 71, 133-149

| Circle the letter that best fits your immediate reaction. | never or only rarely | sometimes | about half the time | frequently | always or almost always |
|---|---|---|---|---|---|
| 11. I find I can get by in most assessments by memorising key sections rather than trying to understand them. | A | B | C | D | E |
| 12. I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra. | A | B | C | D | E |
| 13. I work hard at my studies because I find the material interesting. | A | B | C | D | E |
| 14. I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes. | A | B | C | D | E |
| 15. I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with topics. | A | B | C | D | E |
| 16. I believe that lecturers shouldn’t expect students to spend significant amounts of time studying material everyone knows won’t be examined. | A | B | C | D | E |
| 17. I come to most classes with questions in mind that I want answering. | A | B | C | D | E |
| 18. I make a point of looking at most of the suggested readings that go with the lectures. | A | B | C | D | E |
| 19. I see no point in learning material which is not likely to be in the examination. | A | B | C | D | E |
| 20. I find the best way to pass examinations is to try to remember answers to likely questions. | A | B | C | D | E |


From the British Journal of Educational Psychology (2001), 71, 133-149

**SCORING KEY FOR THE R-SPQ-2F**

The responses to items are scored as follows:

A = 1 B = 2 C = 3 D = 4 E = 5

To obtain main scale scores add item scores as follows:

Deep Approach (DA) = 1 + 2 + 5 + 6 + 9 + 10 + 13 + 14 + 17 + 18

Surface Approach (SA) = 3 + 4 + 7 + 8 + 11 + 12 + 15 + 16 + 19 + 20

Subscale scores can be calculated as follows:

Deep Motive (DM) = 1 + 5 + 9 + 13 + 17

Deep Strategy (DS) = 2 + 6 + 10 + 14 + 18

Surface Motive (SM) = 3 + 7 + 11 + 15 + 19

Surface Strategy (SS) = 4 + 8 + 12 + 16 + 20


From the British Journal of Educational Psychology (2001), 71, 133-149

# APPENDIX C - THE INITIAL VERSION OF THE RATIONALE BEHIND TACRR

**TOTAL SCORE = 80**

For each question, scores can be allocated as follows:

**1. How much of the relevant clinical information is identified?**

***General:*** The first step in clinical reasoning is identifying relevant clinical information. A student's ability to identify relevant clinical information (information may be a symptom, a sign or an investigation result) provided in the examination is demonstrated by their incorporating it into a hypothesis for explaining the patient's illness(es). Relevant clinical information may also include negative findings (eg a negative pregnancy test in a woman with right iliac fossa pain).

***All (5):*** The student incorporates almost all (>90%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***Most (4):*** The student incorporates most (76-90%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***Some (3):*** The student incorporates some (51-75%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***A Little (2):*** The student incorporates a little (26-50%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***Very Little (1):*** The student incorporates very little (10-25%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***Almost None (0):*** The student incorporates almost none (<10%) of the relevant clinical information that is provided into their hypotheses of the mechanism of the patient's illness(es).

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**2. How well is the relevant clinical information utilised with appropriate weighting in the student's hypotheses?**

***General:*** As explained above, clinical reasoning involves being able to identify relevant clinical information. However, clinical reasoning also involves students utilising this information with appropriate weighting in their hypotheses for explaining the patient's illness. Some symptoms, signs or investigation results may also have varying significance according to the other clinical information provided.

***Very Well (10):*** The student utilises the relevant clinical information very well in their hypotheses. The important, relevant clinical information is almost always (>90% of the time), included in the student's hypotheses and almost always (>90% of the time), accorded more weight than information of lesser importance.

***Well (8):*** The student utilises the relevant clinical information well in their hypotheses. Most of the time (76-90% of the time), the important, relevant clinical information is included in the student's hypotheses and most of the time (76-90% of the time), it is accorded more weight than information of lesser importance.

***Averagely (6):*** The student utilises the relevant clinical information averagely in their hypotheses. Some of the time (51-75% of the time), the important, relevant clinical information is included in the student's hypotheses and some of the time (51-75% of the time), it is accorded more weight than information of lesser importance.

***Poorly (4):*** The student utilises the relevant clinical information poorly in their hypotheses. It is not often (26-50% of the time), that the important, relevant clinical information is included in the student's hypotheses and not often (26-50% of the time), is it accorded more weight than information of lesser importance.

***Very Poorly (2):*** The student utilises the relevant clinical information very poorly in their hypotheses. Hardly ever (10-25% of the time), is the important, relevant clinical information is included in the student's hypotheses and hardly ever (10-25% of the time), is it accorded more weight than information of lesser importance.

***Almost Not At All (0):*** The student does not utilise the relevant clinical information in their hypotheses. The important, relevant clinical information is almost never (<10% of the time), included in the student's hypotheses and almost never (<10% of the time), is it accorded more weight than information of lesser importance.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**3. How often are the detailed hypotheses logical?**

***General:*** In order to demonstrate sound clinical reasoning, the hypotheses a student makes must be logical. A student's hypotheses are considered logical if the clinical information given about the patient can be reasonably explained by the outlined mechanisms for the hypotheses.

***Always (10):*** The mechanisms outlined in the student's hypotheses almost always (>90% of the time), reasonably explain the clinical information provided about the patient.

***Most of the Time (8):*** Most of the time (76-90% of the time), the mechanisms outlined in the student's hypotheses reasonably explain the clinical information provided about the patient.

***Often (6):*** The mechanisms outlined in the student's hypotheses often (51-75% of the time), reasonably explain the clinical information provided about the patient.

***Sometimes (4):*** The mechanisms outlined in the student's hypotheses sometimes (26-50% of the time), reasonably explain the clinical information provided about the patient.

***Not Very Often (1):*** It is not very often (10-25% of the time), that the mechanisms outlined in the student's hypotheses reasonably explain the clinical information provided about the patient.

***Almost Never (0):*** The mechanisms outlined in the student's hypotheses almost never (<10% of the time), reasonably explain the clinical information provided about the patient.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

4. **How well do the hypotheses take into account epidemiological considerations?**

***General:*** Epidemiological considerations are important to take into account when reasoning clinically because the age, sex, race, behaviour and environment of a patient can dramatically change the probability of a hypothesis explaining a patient's illness.

***Very well (5):*** Almost all (>90%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Well (4):*** Most (76-90%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Averagely (3):*** Some (51-75%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Poorly (2):*** Few (26-50%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Very Poorly (1):*** Very few (10-25%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Almost Not At All (0):*** Almost none (<10%) of the student's hypotheses take into account the epidemiological considerations impacting upon the case.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

5. **How often are the hypothesised mechanisms for the symptoms, signs and investigation results correct?**

***General:*** The mechanism for a symptom, sign or investigation result displays a student's knowledge of physiological processes and basic science. One cannot practise sound clinical reasoning without a scientific knowledge base.

***Almost Always (15):*** Almost all (>90%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Most of the Time (12):*** Most (76-90%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Often (9):*** Some (51-76%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Sometimes (6):*** A little or few (26-50%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Not Very Often (3):*** Very little or very few (10-25%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Almost Never (0):*** Almost none (<10%), of the student's mechanisms for the symptoms, signs and/or investigation results are correct.

***Not Attempted (0):*** The student has not attempted to make mechanisms to explain the patient's symptoms, signs or investigation results (or has not attempted this question of the examination paper).

**6. How often, when discussing ideas, are the steps in reasoning logical?**

***General:*** Sound clinical reasoning involves an understanding of how one thing leads to another in physiological processes. A student's ability to outline the logical steps involved in a hypothesis (for a patient's illness(es)) or a mechanism (for the patient's symptoms, signs or investigation results) they have outlined in their answers to the examination is an indication of their knowledge base and knowledge is an essential ingredient for sound clinical reasoning.

***Almost Always (10):*** Almost all (>90%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Most of the Time (8):*** Most (76-90%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Often (2):*** Many (26-50%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Sometimes (6):*** A few (10-25%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Not Very Often (4):*** Very Few (<10%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Almost Never (0):*** Almost none (<10%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's illness(es) and/or their symptoms, signs or investigation results (or has not attempted this question of the examination paper).

7. **How often are the individual steps in reasoning supported with relevant clinical information from this case?**

***General:*** Clinical reasoning involves knowing how one's knowledge applies to this case in particular. It is of no use to have knowledge and not know how to apply it. Students need to use the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Almost Always (10):*** The student almost always (>90% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses a for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Most of the Time (8):*** Most of the time (76-90% of the time), the student includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Often (6):*** The student often (51-75% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses and mechanisms for explaining the patient's illness.

***Sometimes (4):*** The student sometimes (26-50% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Not Very Often (2):*** It is not very often (10-25% of the time), that the student includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Almost Never (0):*** The student almost never (<10% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, signs or investigation results.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, signs or investigation results (or has not attempted this question of the examination paper).

**8. The quality of the identified learning issues is…**

***General:*** Recognising when one lacks adequate knowledge in order to (1) logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or (2) to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable is an important part of clinical reasoning. However, equally important for being able to do these same things is being able to pinpoint what knowledge is needed.

***Excellent (5):*** The student almost always (>90% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Good (4):*** Most of the time (76-90% of the time), the student correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Adequate (3):*** The student has often (51-75% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Poor (2):*** The student sometimes (26-50% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Very Poor (1):*** It is not very often (10-25% of the time), that the student correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Extremely Poor (0):*** The student almost never (<10% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Not Attempted (0):*** The student has not written any learning issues (or has not attempted this question of the examination paper).

**9. In supporting the clinical reasoning process, I consider this student's knowledge level to be…**

***General:*** One cannot practise sound clinical reasoning without a scientific knowledge base. Considering the level of a student's knowledge in the examination is an important part of assessing their clinical reasoning.

***Excellent (5):*** In supporting their clinical reasoning, this student's knowledge level is considered to be excellent. I have identified almost no (<90%), erroneous information in their answers to the examination.

***Good (4):*** In supporting their clinical reasoning, this student's knowledge level is considered to be good. I have identified a few (10-25%), pieces of erroneous information in their answers to the examination, and none (0%), would mean the health outcome for this patient would be adversely affected.

***Adequate (3):*** In supporting their clinical reasoning, this student's knowledge level is considered to be adequate. I have identified some (26-50%), pieces of erroneous information in their answers to the examination, but none (0%), would mean the health outcome for this patient would be adversely affected.

***Poor (2):*** In supporting their clinical reasoning, this student's knowledge level is considered to be poor. I have identified some (51-75%), pieces of erroneous information in their answers to the examination, and a few (10-25%), would mean the health outcome for this patient would be adversely affected.

***Very Poor (1):*** In supporting their clinical reasoning, I judge that this student's knowledge level is very poor. I have identified many (51-75%), pieces of erroneous information in their answers to the examination, and some (26-50%), would mean the health outcome for this patient would be adversely affected.

***Extremely Poor (0):*** In supporting their clinical reasoning, I judge that this student's knowledge level is extremely poor. Most (76-90%), of the information in their answers to the examination is erroneous, and much of it (51-75%), would mean the health outcome for this patient would be adversely affected.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, signs or investigation results (or has not attempted the examination paper).

**10. I consider the student's overall approach to the clinical case to be…**

***General:*** One cannot practise sound clinical reasoning without a scientific knowledge base. However, having a knowledge base does not ensure that one knows how to apply this knowledge to the case at hand. Therefore it is important to examine a student's overall approach to the examination and consider how they apply what they know to the clinical case at hand.

***Excellent (5):*** I consider the student's overall approach to the clinical case to be excellent. The student almost always (>90% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student almost always (>90% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also almost always (100% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms, signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Good (4):*** I consider the student's overall approach to the clinical case to be good. Most of the time (76-90% of the time), the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). Most of the time (76-90% of the time), the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining theit hypotheses. Most of the time (76-90% of the time), the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms, signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Adequate (3):*** I consider the student's overall approach to the clinical case to be adequate. The student often (51-75% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student often (51-75% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also often (51-75% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms, signs or investigation results or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Poor (2):*** I consider the student's overall approach to the clinical case to be poor. It is not often (10-25% of the time), that the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). It is not often (10-25% of the time), that the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. It is not often (10-25% of the time), that the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis or mechanism for a patient's illness or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Very Poor (1):*** I consider the student's overall approach to the clinical case to be very poor. It is not often (10-25% of the time), that the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). It is not often (10-25% of the time), that the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. It is not often (10-25% of the time), that the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis or mechanism for a patient's illness or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Extremely Poor (0):*** I consider the student's overall approach to the clinical case to be extremely poor. The student almost never (<10% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student almost never (<10% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also almost never (<10% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis or mechanism for a patient's illness or to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, signs or investigation results and has not identified learning issues (or has not attempted the examination paper).

# APPENDIX D - THE FINAL VERSION OF THE RATIONALE FOR TACRR

## INTRODUCTION TO THE MANUAL

### *The Purpose of TACRR*

The Anderson Clinical Reasoning Rubric (TACRR) affords a measure of a student's clinical reasoning ability at any one point in time. Clinical reasoning involves

- analysing information in a clinical case,
- identifying the relative significance of the details given,
- hypothesising mechanisms for the symptoms, signs and investigation results detailed by applying relevant prior knowledge to this particular case,
- discussing ideas in a logical manner,
- supporting individual steps in the reasoning process with relevant findings and specific information,
- asking questions to clarify particulars/details within the case,
- identifying areas where further knowledge is required,
- re-evaluating learning priorities in response to new information/discussion
- refining mechanism hypotheses in light of new information/discussion
- summarising reasoning and evidence for the working hypothesis and distinguishing it from competing/alternative hypotheses.

TACRR was designed for assessing a medical students' examination paper at The University of Adelaide Medical School in 2004 and 2005.

***How to use TACRR***

In order to attain acceptable inter-rater reliability between different users of TACRR assessing the same examination paper, it is recommended that assessors meet to discuss the ideal answers for the paper before using the rubric. This minimises discrepancies between the marks awarded by assessors for the same standard of clinical reasoning.

When analysing the examination paper, assessors are to award marks for Group A questions in TACRR (questions 1 – 4) only for information contained in the student's answer for the hypothesis section of the examination paper.

When analysing the examination paper, assessors are to award marks for the Group B question in TACRR (question 5) only for information contained in the student's answer for the mechanism section of the examination paper.

When analysing the examination paper, assessors are to award marks for Group C questions in TACRR (questions 6 + 7) only for information contained in the student's answer for the hypothesis and mechanism sections of the examination paper.

When analysing the examination paper, assessors are to award marks for the Group D question in TACRR (question 8) only for information contained in the student's answer for the learning issues section of the examination paper.

When analysing the examination paper, assessors are to award marks for Group E questions in TACRR (questions 9 + 10) for information contained in the student's answer for the hypothesis, mechanism and learning issues sections of the examination paper.

***Scoring TACRR***

The number of marks that may be awarded for each question in TACRR is indicated on the rubric. The maximum total score a student may achieve on TACRR is 100 marks.

The rationale outlined in the following pages may be used as a guide for any assessor using TACRR to analyse an examination paper. This manual is designed to help to objectify the subjective assessment made by an assessor when analyzing students' answers to an examination paper with TACRR. It clarifies what marks are being awarded for, and what skills the assessor is indicating the student has demonstrated in their examination paper.

**1. How much of the relevant clinical information is identified?**

***General:*** The first step in clinical reasoning is identifying relevant clinical information. A student's ability to identify relevant clinical information (information may be a symptom, a sign or an investigation result) provided in the examination is demonstrated by their incorporating it into a hypothesis for explaining the patient's illness(es). Relevant clinical information may also include negative findings (eg a negative pregnancy test in a woman with right iliac fossa pain).

***Almost All (10):*** The student incorporates almost all (>90%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***Most (8):*** The student incorporates most (76-90%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***Some (6):*** The student incorporates some (51-75%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***A Little (4):*** The student incorporates a little (26-50%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***Very Little (2):*** The student incorporates very little (10-25%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***Almost None (0):*** The student incorporates almost none (<10%) of the relevant clinical information that is provided into their hypotheses for the patient's illness(es).

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**2. How well is the relevant clinical information utilised with appropriate weighting in the student's hypotheses?**

***General:*** As explained above, clinical reasoning involves being able to identify relevant clinical information. However, clinical reasoning also involves students utilising this information with appropriate weighting in their hypotheses for explaining the patient's illness(es). Some symptoms, signs or investigation results may also have varying significance according to the other clinical information provided.

***Very Well (10):*** The student utilises the relevant clinical information very well in their hypotheses. The important, relevant clinical information is almost always (>90% of the time), included in the student's hypotheses and almost always (>90% of the time), accorded more weight than information of lesser importance.

***Well (8):*** The student utilises the relevant clinical information well in their hypotheses. Most of the time (76-90% of the time), the important, relevant clinical information is included in the student's hypotheses and most of the time (76-90% of the time), it is accorded more weight than information of lesser importance.

***Averagely (6):*** The student utilises the relevant clinical information averagely in their hypotheses. Some of the time (51-75% of the time), the important, relevant clinical information is included in the student's hypotheses and some of the time (51-75% of the time), it is accorded more weight than information of lesser importance.

***Poorly (4):*** The student utilises the relevant clinical information poorly in their hypotheses. It is not often (26-50% of the time), that the important, relevant clinical information is included in the student’s hypotheses and not often (26-50% of the time), is it accorded more weight than information of lesser importance.

***Very Poorly (2):*** The student utilises the relevant clinical information very poorly in their hypotheses. Hardly ever (10-25% of the time), is the important, relevant clinical information is included in the student’s hypotheses and hardly ever (10-25% of the time), is it accorded more weight than information of lesser importance.

***Almost Not At All (0):*** The student does not utilise the relevant clinical information in their hypotheses. The important, relevant clinical information is almost never (<10% of the time), included in the student’s hypotheses and almost never (<10% of the time), is it accorded more weight than information of lesser importance.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**3. How often are the detailed hypotheses appropriate?**

***General:*** In order to demonstrate sound clinical reasoning, the hypotheses a student makes must be appropriate. A student’s hypotheses are considered appropriate if the clinical information given about the patient can be reasonably explained by the outlined hypotheses.

***Almost Always (10):*** The hypotheses the student has outlined almost always (>90% of the time), reasonably explain the clinical information provided about the patient.

***Most of the Time (8):*** Most of the time (76-90% of the time), the hypotheses the student has outlined reasonably explain the clinical information provided about the patient.

***Often (6):*** The hypotheses the student has outlined often (51-75% of the time), reasonably explain the clinical information provided about the patient.

***Sometimes (4):*** The hypotheses the student has outlined sometimes (26-50% of the time), reasonably explain the clinical information provided about the patient.

***Not Very Often (2):*** It is not very often (10-25% of the time), that the hypotheses the student has outlined reasonably explain the clinical information provided about the patient.

***Almost Never (0):*** The hypotheses the student has outlined almost never (<10% of the time), reasonably explain the clinical information provided about the patient.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**4. How well do the hypotheses take into account the timeline considerations inherent in the case?**

***General:*** The timing of a patient's symptoms is important to take into account when reasoning clinically because it can dramatically change the probability of a hypothesis explaining a patient's illness.

***Very well (10):*** Almost all (>90%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Well (8):*** Most (76-90%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Averagely (6):*** Some (51-75%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Poorly (4):*** Few (26-50%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Very Poorly (2):*** Very few (10-25%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Almost Not At All (0):*** Almost none (<10%) of the student's hypotheses take into account the timeline considerations inherent in the case.

***Not Attempted (0):*** The student has not attempted to make hypotheses (or has not attempted this question of the examination paper).

**5. How much of the hypothesised mechanisms for the symptoms, and/or signs and/or investigation results are correct?**

***General:*** The mechanism for a symptom, sign or investigation result displays a student's knowledge of physiological processes and basic science. One cannot practise sound clinical reasoning without a scientific knowledge base.

***Almost All (10):*** Almost all (>90%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***Most (8):*** Most (76-90%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***Some (6):*** Some (51-76%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***A Little (4):*** A little or few (26-50%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***Very Little (2):*** Very little or very few (10-25%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***Almost None (0):*** Almost none (<10%), of the student's mechanisms for the symptoms, and/or signs and/or investigation results are correct.

***Not Attempted (0):*** The student has not attempted to make mechanisms to explain the patient's symptoms, signs or investigation results (or has not attempted this question of the examination paper).

6. **How often, when discussing ideas through mechanisms and/or hypotheses, are the steps in reasoning logical?**

***General:*** Sound clinical reasoning involves an understanding of how one thing leads to another in physiological processes. A student's ability to outline the logical steps involved in a hypothesis (for a patient's illness(es)) and/or a mechanism (for the patient's symptoms, and/or signs and/or investigation results) they have outlined in their answers to the examination is an indication of their knowledge base and knowledge is an essential ingredient for sound clinical reasoning.

***Almost Always (10):*** Almost all (>90%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Most of the Time (8):*** Most (76-90%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Often (6):*** Many (26-50%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Sometimes (4):*** A few (10-25%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Not Very Often (2):*** Very Few (<10%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Almost Never (0):*** Almost none (<10%), of the steps in reasoning detailed in the student's answer to the examination are logical.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's illness(es) and/or their symptoms, signs or investigation results (or has not attempted this question of the examination paper).

7. **How often are the individual steps in reasoning included in mechanisms and/or hypotheses supported with relevant clinical information from this case?**

***General:*** Clinical reasoning involves knowing how one's knowledge applies to this case in particular. It is of no use to have knowledge and not know how to apply it. Students need to use the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and/or their mechanisms for explaining the patient's symptoms, and/or signs and/or or investigation results.

***Almost Always (10):*** The student almost always (>90% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses a for explaining the patient's illness(es) and/or their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Most of the Time (8):*** Most of the time (76-90% of the time), the student includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and/or their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Often (6):*** The student often (51-75% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and/or their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Sometimes (4):*** The student sometimes (26-50% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Not Very Often (2):*** It is not very often (10-25% of the time), that the student includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Almost Never (0):*** The student almost never (<10% of the time), includes the relevant clinical information provided to support the individual steps in the reasoning demonstrated in their hypotheses for explaining the patient's illness(es) and their mechanisms for explaining the patient's symptoms, and/or signs and/or investigation results.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, and/or signs and/or investigation results (or has not attempted this question of the examination paper).

**8. The usefulness or quality of the identified learning issues is…**

***General:*** Recognising when one lacks adequate knowledge in order to (1) logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results or (2) to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable is an important part of clinical reasoning. However, equally important for being able to do these same things is being able to pinpoint what knowledge is needed.

***Excellent (5):*** The student almost always (>90% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Good (4):*** Most of the time (76-90% of the time), the student correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Adequate (3):*** The student has often (51-75% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Poor (2):*** The student sometimes (26-50% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Very Poor (1):*** It is not very often (10-25% of the time), that the student correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Extremely Poor (0):*** The student almost never (<10% of the time), correctly identifies the areas where their knowledge is lacking and pinpoints the relevant knowledge needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms signs or investigation results and to decide which of two or more competing proposed hypotheses for explaining the patient's illness is more probable.

***Not Attempted (0):*** The student has not written any learning issues (or has not attempted this question of the examination paper).

**9. I consider this student's medical knowledge level to be…**

***General:*** One cannot practise sound clinical reasoning without a medical scientific knowledge base. Considering the level of a student's knowledge in the examination is an important part of assessing their clinical reasoning. It is also important that the student is being marked on knowledge that pertains to the case (otherwise students could strategise, for example by not explaining a patient's symptoms of pancreatitis but instead detailing a mechanism they know well, such as an explanation for the symptoms of epilepsy).

***Excellent (10):*** This student's medical knowledge of the issues in the case is considered to be at an excellent level for a Year 1. I have identified almost no (<90%), erroneous information in their answers to the examination.

***Good (8):*** This student's medical knowledge of the issues in the case is considered to be at a good level for a Year 1. I have identified a few (10-25%), pieces of erroneous information in their answers to the examination, and none (0%), would mean the health outcome for this patient would be adversely affected.

***Adequate (6):*** This student's medical knowledge of the issues in the case is considered to be at an average level for a Year 1. I have identified some (26-50%), pieces of erroneous information in their answers to the examination, but none (0%), would mean the health outcome for this patient would be adversely affected.

***Poor (4):*** This student's medical knowledge of the issues in the case is considered to be at poor level for a Year 1. I have identified some (51-75%), pieces of erroneous information in their answers to the examination, and/or a few (10-25%), would mean the health outcome for this patient would be adversely affected.

***Very Poor (2):*** This student's medical knowledge of the issues in the case is considered to be at a very poor level for a Year 1. I have identified many (51-75%), pieces of erroneous information in their answers to the examination, and/or some (26-50%), would mean the health outcome for this patient would be adversely affected.

***Extremely Poor (0):*** This student's medical knowledge of the issues in the case is considered to be at an extremely poor level for a Year 1. Most (76-90%), of the information in their answers to the examination is erroneous, and/or much of it (51-75%), would mean the health outcome for this patient would be adversely affected.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, signs or investigation results (or has not attempted the examination paper).

**10. I consider the student's overall approach to the clinical case to be…**

***General:*** One cannot practise sound clinical reasoning without a scientific knowledge base. However, having a knowledge base does not ensure that one knows how to apply this knowledge to the case at hand. Therefore it is important to examine a student's overall approach to the examination and consider how they apply what they know to the clinical case at hand.

***Excellent (10):*** I consider the student's overall approach to the clinical case to be excellent. The student almost always (>90% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student almost always (>90% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also almost always (>90% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Good (8):*** I consider the student's overall approach to the clinical case to be good. Most of the time (76-90% of the time), the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). Most of the time (76-90% of the time), the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. Most of the time (76-90% of the time), the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Adequate (6):*** I consider the student's overall approach to the clinical case to be adequate. The student often (51-75% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student often (51-75% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also often (51-75% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Poor (4):*** I consider the student's overall approach to the clinical case to be poor. It is not often (10-25% of the time), that the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). It is not often (10-25% of the time), that the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. It is not often (10-25% of the time), that the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Very Poor (2):*** I consider the student's overall approach to the clinical case to be very poor. It is not often (10-25% of the time), that the student uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). It is not often (10-25% of the time), that the student applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. It is not often (10-25% of the time), that the student also identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Extremely Poor (0):*** I consider the student's overall approach to the clinical case to be extremely poor. The student almost never (<10% of the time), uses relevant clinical information with appropriate weighting to make correct hypotheses for logically explaining the patient's illness(es). The student almost never (<10% of the time), applies the relevant clinical information to support the reasoning inherent in the mechanisms they outline for explaining their hypotheses. The student also almost never (<10% of the time), identifies areas where their knowledge is lacking and pinpoints what knowledge is needed in order to logically explain a hypothesis for a patient's illness(es) or a mechanism for the patient's symptoms and/or signs, and/or investigation results and/or to decide which of two or more competing proposed hypotheses for explaining the patient's illness(es) is more probable.

***Not Attempted (0):*** The student has not attempted to make hypotheses or mechanisms to explain the patient's symptoms, signs or investigation results and has not identified learning issues (or has not attempted the examination paper).

# APPENDIX E - THE DEVELOPMENT OF TACRR

Table E1 - TACRR 2

| | **The Anderson Clinical Reasoning Rubric (TACRR)** | | | | | | **(TACRR 2)** | |
|---|---|---|---|---|---|---|---|---|
| 1 | How much of the relevant clinical information is identified? | All<br>5 | Most<br>4 | Some<br>3 | A Little<br>2 | Very Little<br>1 | None<br>0 | Not Attempted<br>0 |
| 2 | How well is the relevant clinical information utilised with appropriate weighting in the student's hypotheses? | Extremely well<br>5 | Very well<br>4 | Well<br>3 | Poorly<br>2 | Very Poorly<br>1 | Not at all<br>0 | Not Attempted<br>0 |
| 3 | How often are the detailed hypotheses logical? | Always<br>5 | Most of the time<br>4 | Sometimes<br>3 | Not Very Often<br>2 | Hardly Ever<br>1 | Never<br>0 | Not Attempted<br>0 |
| 4 | How well do the hypotheses take into account epidemiological considerations? | Extremely well<br>5 | Very well<br>4 | Well<br>3 | Poorly<br>2 | Very Poorly<br>1 | Not at all<br>0 | Not Attempted<br>0 |
| 5 | How much of the hypothesised mechanism for a symptom is correct? | All<br>5 | Most<br>4 | Some<br>3 | A Little<br>2 | Very Little<br>1 | None<br>0 | Not applicable<br>0 |
| 6 | How much of the hypothesised mechanism for a sign is correct? | All<br>5 | Most<br>4 | Some<br>3 | A Little<br>2 | Very Little<br>1 | None<br>0 | Not applicable<br>0 |
| 7 | How much of the hypothesised mechanism for an investigation is correct? | All<br>5 | Most<br>4 | Some<br>3 | A Little<br>2 | Very Little<br>1 | None<br>0 | Not applicable<br>0 |
| 8 | How often, when discussing ideas, are the steps in reasoning logical? | Always<br>5 | Most of the time<br>4 | Sometimes<br>3 | Not Very Often<br>2 | Hardly Ever<br>1 | Never<br>0 | Not Attempted<br>0 |
| 9 | How often are individual steps in reasoning supported with relevant findings from this clinical case? | Always<br>5 | Most of the time<br>4 | Sometimes<br>3 | Not Very Often<br>2 | Hardly Ever<br>1 | Never<br>0 | Not Attempted<br>0 |
| 10 | How often are the identified learning issues logical? | Always<br>5 | Most of the time<br>4 | Sometimes<br>3 | Not Very Often<br>2 | Hardly Ever<br>1 | Never<br>0 | Not Attempted<br>0 |
| 11 | In supporting the clinical reasoning process, I judge this student's knowledge level to be… | Excellent<br>5 | Good<br>4 | Adequate<br>3 | Poor<br>2 | Very Poor<br>1 | Extremely Poor<br>0 | Not Attempted<br>0 |
| 12 | I consider the student's overall approach to the problem to be… | Excellent<br>5 | Good<br>4 | Average<br>3 | Poor<br>2 | Very Poor<br>1 | Extremely Poor<br>0 | Not Attempted<br>0 |

Table E2 - TACRR 3

**The Anderson Clinical Reasoning Rubric (TACRR 3)**

| | Student Name (Last, First) | Student ID | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | How much of the relevant clinical information is identified by being incorporated into the student's hypotheses? | Almost All<br>5 | Most<br>4 | Some<br>3 | A Little<br>2 | Very Little<br>1 | Almost None<br>0 | Not Attempted<br>0 |
| 2 | How well is the relevant clinical information utilised with appropriate weighting in the student's hypotheses? | Very well<br>10 | Well<br>8 | Averagely<br>6 | Poorly<br>4 | Very Poorly<br>2 | Almost Not At All<br>0 | Not Attempted<br>0 |
| 3 | How often are the detailed hypotheses logical? | Almost Always<br>10 | Most of the time<br>8 | Often<br>6 | Sometimes<br>4 | Not Very Often<br>2 | Almost Never<br>0 | Not Attempted<br>0 |
| 4 | How well do the hypotheses take into account epidemiological considerations? | Very well<br>5 | Well<br>4 | Averagely<br>3 | Poorly<br>2 | Very Poorly<br>1 | Almost Not At All<br>0 | Not Attempted<br>0 |
| 5 | How often are the hypothesised mechanisms for the symptoms, signs and investigations correct? | Almost Always<br>15 | Most of the time<br>12 | Often<br>9 | Sometimes<br>6 | Not Very Often<br>3 | Almost Never<br>0 | Not Attempted<br>0 |
| 6 | How often, when discussing ideas, are the steps in reasoning logical? | Almost Always<br>10 | Most of the time<br>8 | Often<br>6 | Sometimes<br>4 | Not Very Often<br>2 | Almost Never<br>0 | Not Attempted<br>0 |
| 7 | How often are individual steps in reasoning supported with relevant clinical information from this case? | Almost Always<br>10 | Most of the time<br>8 | Often<br>6 | Sometimes<br>4 | Not Very Often<br>2 | Almost Never<br>0 | Not Attempted<br>0 |
| 8 | The quality of the identified learning issues is… | Excellent<br>5 | Good<br>4 | Adequate<br>3 | Poor<br>2 | Very Poor<br>1 | Extremely Poor<br>0 | Not Attempted<br>0 |
| 9 | In supporting the clinical reasoning process, I consider this student's knowledge level to be… | Excellent<br>5 | Good<br>4 | Adequate<br>3 | Poor<br>2 | Very Poor<br>1 | Extremely Poor<br>0 | Not Attempted<br>0 |
| 10 | I consider the student's overall approach to the clinical case to be… | Excellent<br>5 | Good<br>4 | Average<br>3 | Poor<br>2 | Very Poor<br>1 | Extremely Poor<br>0 | Not Attempted<br>0 |
| | | | | | | | | Total Score / 80 |

Table E3 - TACRR 4

| **The Anderson Clinical Reasoning Rubric** | **(TACRR 4)** | |
|---|---|---|
| Student Name (Last, First) | Student ID | Score |
| Please award marks for the student's performance in the following areas according to the scale outlined below… | | |
| Identifying the relevant clinical information in the case by incorporating it into an hypothesis. | Maximum score = 5 | |
| Utilising the relevant clinical information in the case with appropriate weighting in the hypotheses. | Maximum score = 10 | |
| Detailing logical hypotheses. | Maximum score = 10 | |
| Taking into account the epidemiological considerations of the case in the hypotheses. | Maximum score = 5 | |
| Hypothesising correct mechanisms for the symptoms, signs and investigations in the case. | Maximum score = 15 | |
| Discussing ideas using logical steps in reasoning. | Maximum score = 10 | |
| Supporting individual steps in reasoning with relevant clinical information from the case. | Maximum score = 10 | |
| Identifying useful learning issues. | Maximum score = 5 | |
| Demonstrating a medical knowledge level appropriate for a Year 1 student. | Maximum score = 10 | |
| The student's overall approach to the clinical case. | Maximum score = 5 | |
| TOTAL | Maximum score = 85 | |

Table E4 - TACRR 5

| | **The Anderson Clinical Reasoning Rubric** | **(TACRR 5)** | |
|---|---|---|---|
| | Student Name (Last, First) Student ID | | |
| | Please award marks for the student's performance in the following areas according to the scale outlined below… | | Score |
| A 1 | Identifying the relevant clinical information in the case by incorporating it into an hypothesis. | Maximum score = 5 | |
| A 2 | Utilising the relevant clinical information in the case with appropriate weighting in the hypotheses. | Maximum score = 10 | |
| A 3 | Detailing logical hypotheses. | Maximum score = 10 | |
| A 4 | Taking into account the timeline considerations inherent in the case in the hypotheses. | Maximum score = 5 | |
| B 5 | Hypothesising correct mechanisms for the symptoms, signs and investigations in the case. | Maximum score = 15 | |
| B 6 | Discussing ideas using logical steps in reasoning. | Maximum score = 10 | |
| B 7 | Supporting individual steps in reasoning with relevant clinical information from the case. | Maximum score = 10 | |
| C 8 | Identifying useful learning issues. | Maximum score = 10 | |
| D 9 | Demonstrating a medical knowledge level appropriate for a Year 1 student. | Maximum score = 15 | |
| D 10 | The student's overall approach to the clinical case. | Maximum score = 10 | |
| | TOTAL | Maximum score = 100 | |

Table E5 - TACRR 6

| | **The Anderson Clinical Reasoning Rubric** | **(TACRR 6)** | |
|---|---|---|---|
| | Student Name (Last, First) Student ID | | |
| | Please award marks for the student's performance in the following areas according to the scale outlined below… | | Score |
| A 1 | Identifying the relevant clinical information in the case by incorporating it into an hypothesis. | Maximum score = 5 | |
| A 2 | Utilising the relevant clinical information in the case with appropriate weighting in the hypotheses. | Maximum score = 10 | |
| A 3 | Detailing appropriate hypotheses. | Maximum score = 10 | |
| A 4 | Taking into account the timeline considerations inherent in the case in the hypotheses. | Maximum score = 5 | |
| B 5 | Hypothesising correct mechanisms for the symptoms, signs and investigations in the case. | Maximum score = 15 | |
| B 6 | Discussing ideas using logical steps in reasoning. | Maximum score = 10 | |
| B 7 | Supporting individual steps in reasoning with relevant clinical information from the case. | Maximum score = 10 | |
| C 8 | Identifying useful learning issues. | Maximum score = 10 | |
| D 9 | Demonstrating a medical knowledge level appropriate for a Year 1 student. | Maximum score = 15 | |
| D 10 | The student's overall approach to the clinical case. | Maximum score = 10 | |
| | TOTAL | Maximum score = 100 | |

## APPENDIX F - THE ORIGINAL VERSION OF TACTT

**Interpretation/Section 1**

For the following test, assume that the short paragraphs are true. You need to judge whether the proposed conclusions listed below logically follow or do not follow logically from the information contained in the short paragraph. If you think that the conclusion DOES follow logically from the information given, mark "a" on the answer sheet for the number given to that conclusion. If you think that the conclusion DOES NOT follow logically from the information given, mark "b" on the answer sheet for the number given to that conclusion. In some cases, more than one listed conclusion may follow logically from the information given. In other cases, none of the conclusions listed below may follow logically from the information given.

a = Conclusion DOES follow logically
b = Conclusion DOES NOT follow logically

A. Today, electroconvulsive therapy (ECT) involves electrically inducing a brief generalised seizure of adequate intensity after administration of a short-acting general anaesthetic and muscle relaxant. ECT became popular as a method to treat psychiatric illnesses in the 1930s, and it continued to be widely used until the 1970s, when the use of pharmacological treatments increased.
    1. ECT was not widely used until 1930.
    2. ECT was not popular until after 1970.
    3. Pharmacological treatments were not used for psychiatric illnesses before 1930.

B. Compliance can be defined as "the extent to which the patient's behaviour coincides with medical advice". Non-compliance with medication is a major problem and may have serious consequences for patient health and wellbeing. However, no readily observable characteristics of poorly compliant patients permit their easy identification.
    4. If the patient does not think like a doctor, they are non-compliant.
    5. If a patient does not take the medication the doctor prescribes, their health and wellbeing is in danger.
    6. There is no was to identify poorly compliant patients.

**Analysis/Section 2a & 2b**

For the following test, assume that the statements are true. There are a number of statements given and then assumptions that may be made by the person making the statement are suggested below. For each suggested assumption, you need to judge whether someone would make this assumption if they were making the statement given above it. If you think that the suggested assumption WOULD be made by the person giving the statement, mark "a" on the answer sheet for the number given to that assumption. If you think that the suggested assumption WOULD NOT be made by the person giving the statement, mark "b" on the answer sheet for the number given to that assumption. In some cases, more than one listed assumption may be made by the person making the statement. In other cases, none of the listed assumptions may be made by the person making the statement.

a = Assumption WOULD be made
b = Assumption WOULD NOT be made

C. Even lazy interns require stamina to work the many hours required of them in the hospital.
   7. All interns require stamina.
   8. Only lazy interns are required to work long hours at the hospital.
   9. Interns that are not lazy do not require stamina

D. People who suffer from diabetes should avoid eating chocolate, icecream and lollies as these foods contain sugar.
   10. People who suffer from diabetes should avoid eating sugar.
   11. People who suffer from diabetes should avoid eating sweet things.
   12. People not suffering from diabetes do not need to be concerned about what they eat.

For the following test, assume that the short paragraphs are true. You need to judge whether the proposed conclusions listed below logically follow or do not follow logically from the information contained in the short paragraph. If you think that the conclusion DOES follow logically from the information given, mark "a" on the answer sheet for the number given to that conclusion. If you think that the conclusion DOES NOT follow logically from the information given, mark "b" on the answer sheet for the number given to that conclusion. In some cases, more than one listed conclusion may follow logically from the information given. In other cases, none of the conclusions listed below may follow logically from the information given.

a = Conclusion DOES follow logically
b = Conclusion DOES NOT follow logically

E. Some medical students are musical. All medical students are smart. Therefore
   13. Some musical medical students are smart.
   14. Some smart people are musical.
   15. No smart people are musical.

F. All good medical textbooks are expensive. All good medical textbooks are worth buying. Therefore
   16. Whatever is worth buying is expensive.
   17. Some expensive things are worth buying.
   18. There are many different things worth buying.

G. Some doctors who are working long hours are enthusiastic about being required to teach medical students. Only young physicians are required to work long hours. Therefore
   19. Some young physicians are enthusiastic about being required to teach medical students.
   20. Some doctors enthusiastic about being required to teach medical students are not young physicians.
   21. A person cannot be enthusiastic about being required to teach medical students and be a young physician.

**Evaluation/Section 3**

For the following test, you are given a question and then presented with proposed answers to this question. For each answer, you need to evaluate whether it is a strong or weak argument. A strong argument is important and directly relates to the question. A weak argument is not important and/or is not directly related to the question. For the following test, assume that the arguments given are true. If you think that the answer given is a STRONG argument, mark “a” on the answer sheet for the number given to that answer. If you think that the answer given is a WEAK argument, mark “b” on the answer sheet for the number given to that answer. In some cases, more than one answer may be a strong argument. In other cases, none of the answers may be a strong argument.

a = STRONG argument
b = WEAK argument

For this test, “should” indicates that it would promote the general welfare of the population.

H. Should electroconvulsive therapy (ECT) be used to treat psychiatric illnesses?

22. Yes; ECT has been shown to be more effective that some antidepressants for major depression, and to be as effective as some medications for acute schizophrenia and mania.
23. No; ECT has side effects.
24. No; ECT is an old treatment that has been used since before 1930.

I. Should every patient who suffers a stroke have their license revoked?

25. Yes; Having had a stroke means that some people cannot perform the movements necessary to drive a vehicle.
26. No; It is unfair to remove somebody’s license because of a medical condition.
27. No; People who suffer strokes are a burden on their carers if they cannot drive themselves anywhere.

J. Should medical students be required to do research as part of their training?

28. No; Students should concentrate on becoming clinically competent doctors – if they want to do research they should do a different degree.
29. Yes; Studies have shown that those students who engage in research become better doctors.
30. No: Students should have the option to do research but it should not be compulsory as it is not a necessary part of becoming a doctor.

**Inference/Section 4**

For the following test, assume that the short paragraphs are true.

You need to decide whether the inferences (conclusions) listed below are DEFINITELY TRUE, PROBABLY TRUE, PROBABLY FALSE, DEFINITELY FALSE or whether there is INSUFFICIENT DATA for you to decide if they are definitely true, probably true, probably false or definitely false, based on the information in the short paragraph. If you think the inference is DEFINITELY TRUE based on the information in the short paragraph, mark "a" on the answer sheet for the number given to that inference. If you think the inference is PROBABLY TRUE based on the information in the short paragraph, mark "b" on the answer sheet for the number given to that inference. If you think the inference is PROBABLY FALSE based on the information in the short paragraph, mark "c" on the answer sheet for the number given to that inference. If you think the inference is DEFINITELY FALSE based on the information in the short paragraph, mark "c" on the answer sheet for the number given to that inference. If you think there is INSUFFICIENT DATA given in the short paragraph for you to make a decision about the inference, mark "e" on the answer sheet for the number given to that inference.

a = DEFINITELY TRUE
b = PROBABLY TRUE
c = PROBABLY FALSE
d = DEFINITELY FALSE
e = INSUFFICIENT DATA

K. Many students volunteer to be involved in drug trials as a way of earning money. Usually healthy young males are selected. Sometimes the trials involve staying in hospital overnight. Other times the people being studied have to have a blood test or give a urine sample. It is wise to know what the trial involves before volunteering to be a part of it.

31. Students volunteering to be involved in drug trials are motivated to do so for the monetary gain.
32. Most people involved in drug trials are over 40 years old.
33. Most people involved in drug trials are international students.
34. All drug trials involve having a blood test or giving a urine sample.
35. Some students see temporary hospitalisation as worthwhile.

L. Many doctors are faced with the task of breaking bad news to patients. How one breaks bad news to a patient can have a huge impact on the way that they respond to that information. Some people argue that many doctors do not have good communication skills. Good communication skills can be learned over time.

36. Teaching doctors communication skills would not alter the way patients respond to bad news.
37. Some general practitioners do not have good communication skills.
38. You are born with good communication skills: you either have them or you do not have them.
39. All medical schools should endeavour to teach communication skills.

M. Some people get severely injured at work. Studies have shown that those people on Workcover recover much more slowly than those who are not on Workcover. Not many people who are self-employed are able to go on Workcover.

40. Those who do not have an alternate source of income return to work sooner than those covered by Workcover.
41. People who do not get severely injured at work recover faster than those who do.
42. Having Workcover is a hindrance as it prevents people from returning to work.
43. If Workcover did not exist, self-employed people would recover from a workplace injury at the same rate as those employed by someone other than themselves.

**Answers**
**(The Original Version of TACTT)**

Interpretation/Section 1

1. a
2. b
3. b

4. b
5. b
6. b

Analysis/Section 2a

7. a
8. b
9. b

10. a
11. b
12. b

Analysis/Section 2a

13. b
14. a
15. b

16. b
17. a
18. b

19. a
20. b
21. b

Evaluation/Section 3

22. a
23. b
24. b

25. a
26. b
27. b

28. b
29. a
30. a

Inference/Section 4

31. b
32. c
33. d
34. d
35. a

36. c
37. b
38. d
39. b

40. a
41. e
42. d
43. b

## APPENDIX G - A MEASURE OF CRITICAL THINKING ABILITY

### TACTT (THE ANDERSON CRITICAL THINKING TEST)

### INSTRUCTIONS

The following test contains five types of questions to examine your ability to think critically. The test will probably take 40 minutes but you may take up to one hour to complete it if necessary.

Please read the questions and mark your answers by circling the appropriate letter next to the question. If you make a mistake, please put a cross through the circle marking the response that you think is incorrect and then circle the correct letter.

For the purpose of this test, please assume that the information provided is true.

**Section 1**

In this section, each short paragraph (A, B, C, D and E) is followed by a list of conclusions that may or may not follow logically from the information contained within the preceding paragraph.

Please note that for each paragraph, all, some or none of the listed conclusions may follow logically from the information provided.

If you think that a particular conclusion **DOES** follow logically from the information given in the paragraph, circle the letter "Y" for the number given to that conclusion.

If you think that a particular conclusion **DOES NOT** follow logically from the information given in the paragraph, circle the letter "N" for the number given to that conclusion.

Y = Yes: Conclusion **DOES** follow logically
N = No: Conclusion **DOES NOT** follow logically

| A. Electroconvulsive therapy (ECT), became popular as a method to treat psychiatric illness in the 1930s. ECT continued to be widely used until the 1970s, when the use of drug treatments increased. | | |
|---|---|---|
| 1. ECT was not widely used until 1930. | Y | N |
| 2. ECT was not popular until after 1970. | Y | N |
| 3. Pharmacological treatments were not used for psychiatric illnesses before 1930. | Y | N |

| B. Compliance can be defined as "the extent to which the patient's behaviour coincides with the doctor's advice". Non-compliance with taking regular medication is a major problem and may have serious consequences for patient health and wellbeing. However, poorly compliant patients are not easily identified. | | |
|---|---|---|
| 4. If the patient does not think like a doctor they are non-compliant. | Y | N |
| 5. If a patient does not take the medication the doctor prescribes, their health and wellbeing may be adversely affected. | Y | N |
| 6. There is no way to identify poorly compliant patients. | Y | N |

**Section 2a**

Y = Yes: Conclusion **DOES** follow logically

N = No: Conclusion **DOES NOT** follow logically

| C. Some medical students are musical. All medical students are smart. Therefore | | |
|---|---|---|
| 7. only some musical medical students are smart. | Y | N |
| 8. no smart people are musical. | Y | N |
| 9. some smart people are musical. | Y | N |

| D. All good medical textbooks are expensive. All good medical textbooks are worth buying. Therefore | | |
|---|---|---|
| 10. whatever is worth buying is expensive. | Y | N |
| 11. some expensive things are worth buying. | Y | N |
| 12. there are many different things worth buying. | Y | N |

| E. Some doctors who work long hours are enthusiastic about being required to teach medical students. Only young physicians work long hours. Therefore | | |
|---|---|---|
| 13. some young physicians are enthusiastic about being required to teach medical students. | Y | N |
| 14. some doctors enthusiastic about being required to teach medical students are not young physicians. | Y | N |
| 15. a person cannot be enthusiastic about being required to teach medical students and be a young physician. | Y | N |

**Section 2b**

In this section, each statement (F and G) is followed by a list of assumptions that may or may not be made by the person making the statement.

Please note that for each statement, all, some or none of the listed assumptions may be made by the person making the statement.

If you think that a particular assumption WOULD be made by the person making the statement, circle the letter "Y" on the answer sheet for the number given to that assumption.

If you think that a particular assumption WOULD NOT be made by the person making the statement, circle the letter "N" on the answer sheet for the number given to that assumption.

Y = Yes: Assumption **WOULD** be made

N = No: Assumption **WOULD NOT** be made

| F. Even lazy interns require stamina to work the many hours required of them at the hospital. | | |
|---|---|---|
| 16. Only lazy interns are required to work long hours at the hospital. | Y | N |
| 17. All interns require stamina. | Y | N |
| 18. Interns who are not lazy do not require stamina. | Y | N |

| G. People who suffer from diabetes should avoid eating chocolate, icecream and lollies as these food items contain sugar. | | |
|---|---|---|
| 19. People who suffer from diabetes should avoid having sugar in their coffee. | Y | N |
| 20. People who suffer from diabetes should avoid eating sweet things. | Y | N |
| 21. People not suffering from diabetes do not need to be concerned about what they eat. | Y | N |

**Section 3**

In this section, each question (H, I and J) is followed by responses to this question (i.e. “yes” or “no”). After each response there is a supporting argument, and together the response and argument make up a numbered answer.

For each answer, you need to evaluate the strength of the argument. A strong argument is important and directly relates to the question. A weak argument is not important and/or is not directly related to the question.

Please note that for each statement, all, some or none of the numbered answers may be a strong argument, and that you are not being asked to identify with the argument presented, only to evaluate its strength.

For this test, “should” indicates that it would promote the general welfare of the population.

If you think the answer given is a STRONG argument, circle the letter “S” on the answer sheet for the number given to that answer.

If you think the answer given is a WEAK argument, circle the letter “W” on the answer sheet.

S = **STRONG** argument

W = **WEAK** argument

| H. Should electroconvulsive therapy (ECT), be used to treat psychiatric illnesses? | | |
|---|---|---|
| 22. No; ECT is a very old treatment. | S | W |
| 23. No; ECT has side effects. | S | W |
| 24. Yes; ECT is an internationally recognised psychiatric treatment. | S | W |

a = **STRONG** argument
b = **WEAK** argument

| | | |
|---|---|---|
| I. Should every patient who suffers an epileptic seizure have their license suspended? | | |
| 25. No; It is unfair to remove someone's license because of a medical condition. | S | W |
| 26. Yes; Having had a seizure means that someone is not safe to drive a vehicle. | S | W |
| 27. No; People who suffer from epilepsy are a burden on their carers if they cannot drive themselves anywhere. | S | W |

| | | |
|---|---|---|
| J. Should medical students be required to do research as part of their training? | | |
| 28. No; Students should concentrate on becoming clinically competent doctors – if they want to do research they should be doing a different degree. | S | W |
| 29. Yes; studies have shown that those students who engage in research become better doctors. | S | W |
| 30. No; Students should have the option to do research but it should not be compulsory as it is not a necessary part of becoming a doctor. | S | W |

**Section 4**

In this section, each short paragraph (K and L) is followed by a list of inferences (conclusions). You need to decide on the degree of truth or falsehood of these inferences based on the information given in the short paragraphs, or state that there is insufficient data in the paragraph for you to make a decision.

If you think the inference is **DEFINITELY TRUE**, circle the letter “A” for the number given to that inference.

If you think the inference is **PROBABLY TRUE**, circle the letter “B” for the number given to that inference.

If you think the inference is **PROBABLY FALSE**, circle the letter “C” for the number given to that inference.

If you think the inference is **DEFINITELY FALSE**, circle the letter “D” for the number given to that inference.

If you think there is **INSUFFICIENT DATA** for you to make a decision about the inference, circle the letter “E” for the number given to that inference.

A = DEFINITELY TRUE
B = PROBABLY TRUE
C = PROBABLY FALSE
D = DEFINITELY FALSE
E = INSUFFICIENT DATA

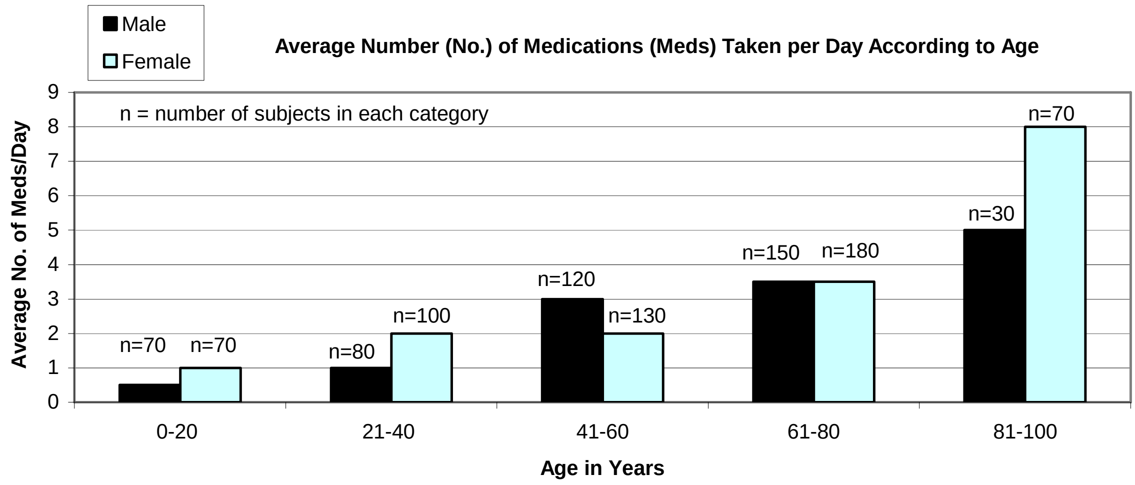
| | | | | | |
|---|---|---|---|---|---|
| K. Many students volunteer to be involved in drug trials as a way of earning money. Usually healthy young males are selected. Sometimes the trials involve staying in hospital overnight. Often the people being studied have to have a blood test or give a urine sample. It is wise to know what the trial involves before volunteering to be a part of it. | A = DEFINITELY TRUE<br>B = PROBABLY TRUE<br>C = PROBABLY FALSE<br>D = DEFINITELY FALSE<br>E = INSUFFICIENT DATA | | | | |
| 31. Students volunteering to be involved in drug trials are motivated to do so for the monetary gain. | A | B | C | D | E |
| 32. Most people involved in drug trials are over 40 years old. | A | B | C | D | E |
| 33. Some students are prepared to be temporarily hospitalised in order to earn money. | A | B | C | D | E |

| | | | | | |
|---|---|---|---|---|---|
| L. Many doctors are faced with the task of breaking bad news to patients. How a doctor breaks bad news to a patient can have a huge impact on the way that they respond to that information. Many doctors do not have good communication skills. Good communication skills can be learned over time. | A = DEFINITELY TRUE<br>B = PROBABLY TRUE<br>C = PROBABLY FALSE<br>D = DEFINITELY FALSE<br>E = INSUFFICIENT DATA | | | | |
| 34. Some general practitioners do not have good communication skills. | A | B | C | D | E |
| 35. You are born with good communication skills: you either have them or you do not have them. | A | B | C | D | E |

**Section 5**

Please refer to the graph below in order to answer the questions numbered 36-38. Circle the letter (A, B, C, D or E) underneath the answer to the question that you think is correct.

M.




36. In which age bracket is there the smallest difference between the average number of tablets taken per day by males and the average number of tablets taken per day by females?

| | | | | |
|---|---|---|---|---|
| 0-20 years | 21-40 years | 41-60 years | 61-80 years | 81-100 years |
| A | B | C | D | E |

37. How many women aged 21-40 years old take 1 tablet per day?

| | | | |
|---|---|---|---|
| 100 women | 50 women | 80 women | Cannot tell from given data |
| A | B | C | D |

38. What percentage (%) of the people taking an average of 2 or fewer medications per day are male?

| | | | |
|---|---|---|---|
| 33% | 25% | 67% | 75% |
| A | B | C | D |

**ANSWERS TO TACTT**

Section 1
(Interpretation and Evaluation)
A
1. Y
2. N
3. N

B
4. N
5. Y
6. N

Section 2a (Analysis)
C
7. N
8. N
9. Y

D
10. N
11. Y
12. N

E
13. Y
14. N
15. N

Section 2b (Analysis)

F
16. N
17. Y
18. N

G
19. Y
20. N
21. N

Section 3 (Evaluation)
H
22. W
23. W
24. S

I
25. W
26. S
27. W

J
28. W
29. S
30. S

Section 4 (Inference)
K
31. B
32. D
33. A

L
34. B
35. D

Section 5
(Interpretation and Explanation)
M
36. D
37. D
38. A

# APPENDIX H - INTERVIEW QUESTIONS 2004

## QUESTIONS ABOUT LEARNING

These questions explore students' past and present approaches to learning, defining further whether they choose deep or surface methods. This will complement the data gained by the R-SPQ-2F questionnaires to build a picture of the students' approaches to learning.

### *Past Approaches to learning*

In the past, how have you gone about your learning for exams at school?

What activities do you do when you study/learn things?

In the past, what methods or approaches have been most valuable for your learning?

In the past, have there been times when you've found it difficult to learn 'stuff'?
Under what circumstances did this occur?
How did you go about coping with this?

In the past, was your learning approach different during the period leading up to exams than to the way it was during the rest of the year?
In what ways was it different?
How, if at all, did you vary your approach to learning according to the type of assessment?
How, if at all, did you vary your approach to learning according to the subject you were studying for?

In the past, did you think about how you went about your learning?
What sort of conclusions did you come to?
How did this change your approach to learning?
Would you give me some examples of this?

### *Present Approaches to Learning*

How're you finding your approach to studying is working in medicine so far?

Have you made conscious changes to your approaches to learning since starting at Uni?
If so, what sort of changes have you made?
How are these working for you so far?

What things most influence your motivation to learn at present?

Are there things that interfere with your motivation at this stage?
If so, what sort of things are most important in this regard?

### *Deep and Surface Approaches to Learning*

When actually learning, do you tend to memorise things or try to understand them or a bit of both?
Under what circumstances do you memorise things and what influences you to use this approach?
Under what circumstances do you try to understand things and what influences you to use this approach?

Some people find it easier to learn things that have been clearly defined for them and are separate entities. Other people prefer to see how these bits and pieces all fit into a bigger picture.
Do you have a preference for either of these methods or do you use another approach?
What helps you to decide which approach to use for any particular learning?
How does this work for you?

In Medicine at Adelaide Uni, learning is very self-directed. There can be a degree of uncertainty about what you need to do with the information you find out.
How're you finding this?
What changes, if any, has this caused you to make to your approach to learning?

With the PBL that you're doing, to what extent do you think back about your approach to learning in the cases?
How often do you do this?
How do you go about it?
Have you introduced any changes to your approach to learning as a result of this process?
If so, would you tell me about these?

### *Questions about critical thinking*

Some of these questions overlap with ones above but they primarily explore how students find critically thinking about information in PBL. The questions aim to draw out how the students are self-regulating, and how they interpret, analyse, evaluate, infer, and explain information, to complement data gathered using TACTT.

You have been involved in problem-based learning for about X weeks.
What are your thoughts and experiences of this approach to learning so far?

In this area (PBL) in particular, you have to make decisions about what to learn. What things most influence this decision for you?

In doing PBL, you have to find out a lot of information but are also being asked to apply this information in order to help you to understand a patient's illness (signs and symptoms) and to be able to explain things.
How're you going with this?
What difficulties, if any, have you been having?
How're you going about coping with these?

You are reading a lot of information for your study. Some of it is more reliable than other bits.
How're you getting on with this?
How do you decide that some material is more reliable than others?

### *Questions about clinical reasoning*

Some of these questions overlap with ones above but they primarily explore the development of students' clinical reasoning.

Have you or do you currently think about how you go about your learning?
If yes, what's motivated you to think about your learning?
What sort of conclusions have you come to?
How, if at all, has this changed your approach to learning?
Would you give me some examples of this?

Have you looked at the Year 1 Learning Objectives?
What prompted you to look at them?
Do you use them to determine what to learn and in what depth?
If you do, how is it working for you?
If you don't, why not?

How did you go about your learning in semester 1?

What activities did you do when you studying?

What methods or approaches were most valuable for your learning?

Were there times during semester 1 when you've found it difficult to learn 'stuff'?
Under what circumstances did this occur?
How did you go about coping with this?

In semester 1, was your learning approach different during the period leading up to exams than to the way it was during the rest of the semester?
In what ways was it different?
What learning strategies did you use during swot vac?

How did you find the case analysis?
What did you find easy about this?
What did you find difficult about this?
In what ways, if any, have you had to re-think how you learn for this exam during the semester?
During PBL?
During preparation for exams?
Did your perceptions about how you were going line up with your exam feedback?

Being such a self-directed, problem-based learning course, you may have changed your approach to learning between school and during semester 1 of year 1 medicine, or between semester 1 and semester 2 of year 1 of medicine. On reflection, what might have helped you to make this transition sooner or more effectively?

Have you made conscious changes or are you thinking of making changes to your approach to learning since starting semester 2?
If so, what sort of changes have you made/are you planning on making at Uni?
At home?
What's motivated you to make these changes?
How are these working for you so far?
If not, why didn't you make changes?

What things most influence your motivation to learn at present?

Are there things that interfere with your motivation at this stage?
If so, what sort of things are most important in this regard?

Does discussing your approach to learning, your critical thinking ability or your clinical reasoning have any impact on what you do?

Can you describe your approach to clinical cases for me?
What do you do when you get some history?
How do you go about hypothesising what is happening?
How do you get more history?
How do you use this history?
How do you get physical examination findings?
How do you use these examination findings?
How do you go about devising mechanisms for your hypotheses?
How do you get investigation results?
How do you use these investigation results?
What elements of this whole clinical reasoning process do you find easy?
What elements of this whole clinical reasoning process do you find difficult?

To what extent does the need to reach a diagnosis drive your learning?
How does this influence your approach to learning?
Does this your approach to learning being driven by the need to reach a diagnosis change throughout the case?
How is reaching a diagnosis helpful to your learning?

## APPENDIX I - INTERVIEW QUESTIONS 2005

### THEME 1 - CLINICAL REASONING IN MEDICAL SCHOOL

One of the main aims during medical school is to learn to reason clinically, so that you can become a competent doctor.

How has your clinical reasoning developed over years 1 and 2 of medicine?
What things help the development of your clinical reasoning?
What things hinder the development of your clinical reasoning?
How does PBL help you to fit everything together and develop the ability to reason clinically?
How does Clinical Skills help you to develop the ability to reason clinically?
How does gaining knowledge (through lectures, reading, etc) help you to develop the ability to reason clinically?

### THEME 2 – DEVELOPING KNOWLEDGE FOR CLINICAL REASONING

You have to learn a lot of information in order to progress through medical school. However, learning is only part of the picture.

What helps you to apply what you've learnt and use it to reason through cases?
How do you apply what you've learnt and use it to reason through cases?
What is your motive for applying what you've learnt and developing reasoning?

### THEME 3 – THE ASSESSMENT OF CLINICAL REASONING

One of the ways clinical reasoning is assessed during medical school is by examinations.

How do you practise reasoning clinically in order to pass this part of the examination?
What impact do the examinations have on the development of your clinical reasoning ability?
How much time and effort do you spend applying information that you know compared to just learning the information in the first place?
How do you find applying information and reasoning clinically?
What are the areas you struggle with?
What are the areas that you find easy?

### THEME 4 – DEVELOPING CLINICAL REASONING IN GROUPS

You obviously do learning for medical school in your own time and by yourself. However, you spend much of the week in small groups, as well.

How does learning in a small group help you to develop clinical reasoning?
How do your tutors help you to develop clinical reasoning?
For you, personally, what development of clinical reasoning can occur in groups, and how much has to be developed by you alone?
What type of feedback helps you to get a better understanding about your clinical reasoning?
How has it helped or hindered the development of your clinical reasoning ability?

## THEME 5 – ADVICE FOR CLINICAL REASONING DEVELOPMENT

If you had to give a first year medical student the definition of clinical reasoning, what would you say?
How important is developing clinical reasoning?
What advice would you give someone entering medical school so that they could maximise the development of their clinical reasoning? What pitfalls would you tell them to look out for?

## APPENDIX J – CASE 1 (YEAR 1 SEMESTER 1 2004 EXAMINATION)

Dan Bush is a 20-year old student at University of South Australia. He presents to his local doctor, during his end of year examinations, complaining of diarrhoea for the last 3 weeks. He says he has been passing 6-7 small semi-fluid motions each day since the attack began. The motions are normal in colour but contain bright blood and mucous. He gets bouts of abdominal pain just before he has to have a bowel action. This pain is located in the lower abdomen, more on the left side than the right. It tends to come on shortly before he has to have his bowels open and he has also experienced discomfort in his rectum at this time, along with some urgency to pass a motion once the pain occurs. The pain is relieved, for the time being, by having a bowel action.

His appetite has been only fair during this time, and he "has not been feeling 100%". He has not been nauseated and has not vomited. He has not had a temperature, but from time to time has been "feeling a bit hot and sweaty", mainly when he gets the pain. He acknowledges that he is "pretty worried" about his end of year examinations, which are about to begin. His health through the year has been good and he played football "in the seconds". He has not been outside Adelaide during the year. He has no previous serious illness.

On questioning he recalls that he had a similar but less severe attack of abdominal pain and diarrhoea, during the matriculation examinations, but that attack was not so severe as this and he did not notice any blood or mucus at that time. He saw his local doctor and recalls that he had a rectal examination, which was both uncomfortable and painful at that time. The attack lasted only for 2 weeks and settled down quickly with some anti-diarrhoeal medicine, which his doctor prescribed. No specific diagnosis was made at that time and no further investigations were undertaken. He also had loose motions for a couple of days before the exams in the mid-year.

He is worried about the effect the illness is having on his exam preparation.

1. List below in decreasing order of clinical importance the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Reordered Data (Important Data First) | Significance for this patient | Used in Hypothesis number |
|---|---|---|
| | | |

2. Analyse the data you are given and prepare a short **LIST** (3-5) of hypotheses. Provide evidence from the data for each hypotheses.

3. For **EACH** hypothesis, outline briefly the **important mechanism(s)** involved in producing the clinical features you chose in part 1.

4. For **each** hypothesis/mechanism indicate the **learning issues** you consider will prepare you and be most helpful to you for answering more detailed questions about the patient and for explaining the mechanisms responsible for his abnormal clinical features. Indicate (with an *) those LI's which you consider you already have sufficient prior knowledge.

**An Example Answer for Modified Essay Question Examination Questions for Case 1**

**Hypotheses**

1. I think Dan has a 3 week history of diarrhoea, blood and mucous, abdominal pain relieved by passing stool, urgency, a lack of appetite and a history of an episode of 2 weeks of diarrhoea previously due to ulcerative colitis that has been triggered by examination stress (usually occurs in people aged 20-25 years).

2. I think Dan has a 3 week history of diarrhoea, abdominal pain relieved by passing stool, a lack of appetite and a history of 2 weeks of diarrhoea previously due to Crohn's disease that has been triggered by examination stress (usually occurs in people aged 20-30 years)

3. It is less likely that Dan has diarrhoea due to a gastrointestinal infection as he has not been travelling, there is no history of food poisoning or others around him being unwell, and this diarrhoea has lasted 3 weeks as well as him having a previous episode. There is also no history of fever, nausea or vomiting.

4. I think Dan has abdominal pain due to the distension of the colon

5. I think Dan has blood and mucous in his stools due to inflammation of the colon

**Mechanism**

In genetically susceptible individuals such as Dan, an exaggerated immune response to gut flora is triggered (perhaps by examination stress). This response causes inflammation of the colon mucosa, making it friable and thus mucosal blood vessels bleed and mucus from goblet cells get into the stool. The systemic manifestation of the inflammation may be causing Dan to not feel 100%. In Crohn's Disease this gut inflammation is transmural, discontinuous and can be granulomateous. In Ulcerative Colitis, inflammation is always distal and involves the rectum, and it is more likely to cause blood in the stool and urgency. This makes Ulcerative Colitis a more likely diagnosis in Dan's case. As the inflammation also destroys gut villi and the surface area for absorption of fluid decreases, the stools become more watery and diarrhoea ensues. With increased faeces distending the colon, the muscle layers are stretched, stimulating nerve fibres and thus causing abdominal pain. When stools are passed the distension is relieved and the pain ceases.

**Learning Issues**

What is the mechanism of lower abdominal pain and how can it be relieved by defecation?*
How are watery stools formed and what can cause this?*
What commonly causes blood and mucous in the stools of a 20 year old man?
What causes urgency to defecate?
What are the mechanisms for the systemic manifestations of inflammatory bowel disease?

## APPENDIX K – CASE 2 (YEAR 1 SEMESTER 2 2004 EXAMINATION)

Mr Walter Stevenson is a 49-year old butcher. He is seen in the Emergency Department at 3.45 pm on Saturday, complaining of severe central chest pain. This is crushing in type and has been present unchanged for just over one hour. The pain came on after a barbeque lunch and ‘a few beers’ while he was watching a horse race on television at home. [He had bet on the second place-getter.] He has never had pain like this previously. The pain radiates down the inner side of his left arm and up into the left side of his jaw. It does not radiate into the back.

He began to sweat profusely and has vomited twice - producing partially digested food (meat, ham, eggs and onions - no blood). In the last half hour or so, he has become aware that his breathing is "difficult" and he has been "light headed" when he attempts to stand or to walk. He has been taking over-the-counter medicines for “reflux” for the last 2 years, but otherwise he has been very well and has had no reason to consult a doctor in the last 3 years.

On Examination:

Overweight (BMI 28 kg/m2). Pale, sweating profusely, apprehensive.

Breathing at 22 breaths /minute; not centrally cyanosed. No audible wheeze.

Hands and feet are cold, clammy and cyanosed.

Pulse: 100 beats per minute, occasional irregular beat. JVP: + 3 cms BP: 100/70 Apex beat not palpable. HS: Audible 3$^{rd}$ HS, No murmurs.

Leg pulses: femorals palpable on both sides, but difficult to feel any pulses below the femorals on either side.

Chest: Fine crepitations at both lung bases to the mid-zones. No wheeze.

Abdomen: Soft but mildly tender in epigastrium. No guarding.

ECG (in Emergency Department) shows changes indicative of a full thickness myocardial infarct, antero-laterally. He is in normal sinus rhythm, with an occasional premature ventricular contraction.

1. List below (in **decreasing order of clinical importance**) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
|---|---|---|
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses.

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient's illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new **learning issues** that you identify for this case

**An Example Answer for Modified Essay Question Examination Questions for Case 2**

**Hypotheses**

1. I think Walter has been lightheaded in the last half an hour, has cold and clammy hands and feet, a pulse rate of 100, a BP of 100/70 and is sweating profusely due to being in cardiogenic shock.

2. I think Walter had severe central crushing chest pain for more than one hour that radiated to his left arm and jaw from an antero-lateral myocardial infarct that was due to an occlusion of his coronary artery.

3. I think Walter has been having difficulty breathing in the last half an hour and has bilateral basal crepitations in the lungs due to left heart failure causing pulmonary edema and right heart failure, signified by the raised JVP and third heart sound.

**Mechanisms**

1. Walter being overweight is at risk of atherosclerosis, which would narrow his arteries (causing difficulty feeling distal pulses in his leg). Stress induced sympathetic stimulation of Walter's heart increases its rate and contractility, and thus the oxygen requirement of the heart muscle increases. If the oxygen demand cannot be met because the blood flow is slowed by atherosclerosis, ischaemia of the heart muscle can cause chest pain (angina), which may have been the "reflux" pain Walter was having. The suddenness of Walter's chest pain today indicates that an acute plaque event probably occurred. The atherosclerotic plaque in Walter's coronary artery fissured, ruptured or ulcerated (due to faster blood flow than normal caused by increased coronary output stimulated by the sympathetic response to the race) stimulating platelet adhesion and aggregation causing a mural thrombus to form leading to coronary artery occlusion and infarction of the distal heart muscle deprived of oxygen. Inflammatory mediators released from the infarcted heart muscle stimulated nerve fibres that signaled the chest pain to Walter's brain. However, as the nerves for the heart and the left arm and jaw come from the same part of the spinal cord, this chest pain was also interpreted by Walter's brain as arm and jaw pain (referred pain). The pain also stimulates the vomiting centre in Walter's brain.

2. Walter's myocardial infarct caused decreased heart contractility and cardiac output as the heart muscle was dead. This caused a decrease in blood pressure and Walter went into cardiogenic shock. Inadequate blood pressure (100/70) was sensed by baroreceptors in his carotid arteries which caused increased sympathetic stimulation (increasing the heart rate to 100 beats per minute and stimulating sweating, causing his peripheries to be clammy) in an effort to increase cardiac output. The inadequate blood pressure to the brain was worsened when Walter stood because of gravity. This caused a reduction in the perfusion of brain tissue, hence Walter's lightheadedness. Sympathetic stimulation caused constriction peripheral blood vessels, in an effort to increase the return of blood to the heart (which can lead to increased contraction of sarcomeres or heart muscle) as well as conserve perfusion to other important organs such as the brain. The constriction of

peripheral bloods vessels means the heat of superficial blood flow in the hands and feet is reduced, causing cold peripheries. As heat cannot be dissipated through the constricted vessels in the skin, sweating occurs causing clammy hands and feet. The decreased blood flow to peripheries causes increased oxygen extraction from blood in peripheral tissues. This means a reduced oxygen content of the venous blood in peripheries, seen as cyanosis in the hands and feet.

3. Walter's myocardial infarct means that there is decreased compliance of the left ventricle due to dead muscle and the heart cannot pump efficiently. The increased end-diastolic volume causes a third heart sound. There is a "build up" of blood and pressure in the left ventricle that eventually transmits to the left atrium and then the pulmonary capillaries. This causes increased capillary hydrostatic pressure and the accumulation of interstitial fluid in the alveolar spaces, heard as crepitations on breathing. This interstitial edema stimulates juxtacapillary J receptors which cause Walter's rapid breathing (respiratory rate 22) and a sense of breathlessness as the work of breathing with "stiff lungs" becomes difficult.

**Learning Issues**

Sufficient Prior Knowledge

What is the mechanism of a myocardial infarct?
What is the mechanism for chest pain and associated left arm pain?
What is the mechanism for breathlessness in pulmonary edema?
What is the mechanism of cardiogenic shock?

New Learning Issues

How exactly is a third heart sound created and what is its significance?

## APPENDIX L – CASE 3 (YEAR 2 SEMESTER 1 2005 EXAMINATION)

Ms Pattie Mason, aged 36 presents to her local doctor complaining that she has "arthritis". She tells that both her wrists have been swollen and painful for the last 4 days and this morning both her knees have become painful and are also swollen, so that she is having trouble walking.

Enquiry reveals that she has always had trouble with 'chilblains' during the winter – mainly affecting her fingers and ears. For the last month she has noticed soreness and stiffness of her hands and her toes have also been painful when she first gets up. The stiffness in her hands has been persisting while she has a shower and breakfast, and tends to improve while she is doing the washing up after breakfast. Her feet also improve about that time. She had initially thought she was getting chilblains again as the season became colder, but was aware that the problems in her hands were tending to affect the joints at the base of the fingers rather than at the tips and she had noted that they were a bit swollen too.

She now recalls that she has been struggling with her housework for the last couple of months. She has been feeling tired and 'run down' and lacking in energy. It has been a relief to get the children off to school, so she can have a rest. This is unusual for her. She has wondered if she had a virus, as she had been a bit hot and sweaty from time to time and had also had muscle aches. Her appetite has been less than usual and she has lost some weight (probably 2-3 Kg) in the last couple of months.

She has had no trouble with her eyes and no difficulty with passing urine. She has never had any skin diseases or rashes. She is not troubled with mouth ulcers.

She is happily married with 2 children, aged 10 and 7. Both are well. Periods regular. She has had no vaginal discharge. Taking contraceptive pill since last child born. She has had no serious past illnesses. She had appendectomy at age 18, for acute appendicitis. She has been taking paracetamol for her aches and pains this last month.

On examination:

Anxious woman, of about average build. BMI = 23. Looks slightly pale. Temperature 37.2 °C. Has obvious symmetrical swelling of proximal joints of both hands. Walking is obviously painful.

**CVS:** PR 80 bpm, BP 135/85 mm Hg. HS dual, no murmurs. All pulses palpable and full. **Chest:** clear. **Abdomen:** No masses or tenderness. Liver and spleen not palpable. **NS:** Normal.

**MSK:** Hands: Symmetrical swelling and tenderness over proximal interphalangeal and metacarpal-phalangeal joints. Pain on movement of joints. Weak grip both sides. Distal IP joints not affected. Wrists: swollen, dorsally particularly, tender to touch; pain on movement. All affected joints warm. Knees: both hot and swollen generally; tender to touch and painful on movement. Feet: Symmetrical swelling, warmth and tenderness over all metatarsal phalangeal joints. Neck, Jaw and other large joints: No abnormality present.

**No lymphadenopathy** present, but tender nodules on the extensor surface of both forearms distal to the olecranon processes. Similar non-tender nodules over the occiput.

The doctor tells her she has acute rheumatoid arthritis.

1. List below (in **decreasing order of clinical importance**) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
|---|---|---|
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses.

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient's illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new **learning issues** that you identify for this case

**An Example Answer for Modified Essay Question Examination Questions for Case 3**

**Hypotheses**

1. I think Pattie's rheumatoid arthritis was triggered by a virus (causing her to be a bit hot and sweaty from time to time and have muscle aches)

2. I think Pattie's swollen, warm joints over the last 4 days, her painful joints from the last month and her tender nodules on the extensor surface of both forearms distal to the olecranon processes and similar non-tender nodules over the occiput are due to inflammation from rheumatoid arthritis

3. I think Pattie's pallor, struggling with her housework for the last couple of months, feeling tired and 'run down' and lacking in energy is due to anemia caused by the chronic inflammation of rheumatoid arthritis

4. I think chronic inflammation from the rheumatoid arthritis has made Pattie's appetite decrease and caused her to lose some weight (probably 2-3 Kg) in the last couple of months

**Mechanisms**

1. Rheumatoid arthritis is hypothesised to occur in genetically predisposed individuals (often females of Pattie's age) after an immunological trigger (eg a virus) activates T helper cells. These cells cause an inflammatory response of cytokine TNF and IL-1 and antibody formation which may have initially made Pattie sweaty by resetting her thermostat and to have muscle aches. However, after the virus abates, Pattie's T helper cells continue to cause joint inflammation as they are now stimulated by her own synovial tissue through molecular mimicry, and the autoimmune process continues. Rheumatoid arthritis tends to affect the proximal, interphalangeal, metacarpophalangeal, wrist, elbow, knee, tarsal and metatarsal joints symmetrically, as shown in Pattie.

2. The inflammatory response in Pattie's rheumatoid arthritis means that neutrophils, macrophages and lymphocytes are attracted to the synovium in the affected joints. Enzymes and prostaglandins are released causing destruction of articular cartilage and pannus formation as well as further inflammation of the joint. The extra fluid in the joint makes it stiff to move as well as distending the joint capsule which is rich in nerve fibres and thus moving the joint is painful. The inflammatory response also triggers angiogenesis in the synovial membrane and the increased blood flow to the joints makes them warm. Pattie's nodules are granulomateous lesions around small vessels that have been caused by a vasculitis probably triggered by rheumatoid factor.

3. In rheumatoid arthritis there is chronic inflammation and ineffective erythropoeisis and thus Pattie's haemoglobin is low (anemia) and her red blood cells' do not carry as much oxygen. This causes the blood to appear less 'red' and Pattie looks pale. Also, the reduced oxygenated blood flow means that blood is directed away from peripheral tissues to more important organs, again reducing the redness of skin. The lack of well-oxygenated blood flowing to muscles means Pattie feels tired, 'run down' and lacking in energy.

4. I think the presence of systemic inflammatory mediators from the rheumatoid arthritis has made Pattie's metabolism increase and put her into a catabolic state so that her appetite decreased and she lost weight (probably 2-3 Kg) in the last couple of months.

**Learning Issues**

Sufficient Prior Knowledge

What is the mechanism for Rheumatoid Arthritis?
How does Rheumatoid Arthritis cause stiff, sore joint and why are they more this way in the morning?
What triggers Rheumatoid Arthritis?
What pattern of joints are involved in Rheumatoid Arthritis?

New Learning Issues

How does Rheumatoid Arthritis cause anaemia?
How does Rheumatoid Arthritis cause systemic effects of anorexia etc?
What inflammatory mediators are released in Rheumatoid Arthritis and how do they work?

## APPENDIX M – CASE 4 (YEAR 2 SEMESTER 2 2005 EXAMINATION)

Mr Simon Adams, aged 52, Cabdriver

Mr Adams presents to his local doctor complaining of increasing swelling of his ankles and lower legs for the last 2 weeks, so that now they are swollen to the knee, at the end of the day.

In the last week, he has also noticed that he gets breathless walking up stairs, where previously he did not. In addition, for the last couple of weeks he has been getting up 2 X at night to pass urine, where previously he slept through the night. This encouraged him to take more interest in his urine, and he has noticed that when he passes urine, it causes frothing in the toilet bowl. He has not observed any change in the colour of his urine and specifically denies it has contained blood. Apart from these symptoms, he is reasonably well. He has less energy than usual.

His general health has been good. He has never smoked and takes alcohol in moderation only on social occasions. His only previous major illness was a gall bladder operation for stones 2 years ago – after which he developed a post-operative pulmonary embolus and was treated with anticoagulants for a time. He is taking no medication now apart from aspirin, daily. He has not visited his local doctor since he stopped anticoagulants.

On examination:

Overweight man, slightly pale looking, sitting comfortably in no distress.

He has pitting oedema of both legs to the knees. Swollen legs are not tender. No calf tenderness. Evidence of minor varicosities on both sides. Homan's sign negative both sides.

CVS: PR 76 bpm, BP 165/95 mm Hg. JVP not elevated. HS dual, no murmurs.

All pulses palpable and full. Aorta not palpable or tender and no bruit over the kidneys.

Chest: Some dullness to percussion at both bases and fine crepitations audible at both bases.

Abdomen: No masses or tenderness. Liver and spleen not palpable. No evidence of ascites and no renal angle tenderness.

Dipstick Urinalysis: Nitrates: negative; Sugar: negative; Blood: trace; Protein: 3+ (5 g/100 ml)

1. List below (in **decreasing order of clinical importance**) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
| --- | --- | --- |
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses.

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient's illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new **learning issues** that you identify for this case

**An Example Answer for Modified Essay Question Examination Questions for Case 4**

**Hypotheses**

1. I think Mr Adams has had pitting edema in his legs for 2 weeks, pulmonary edema (breathlessness, dullness to percussion of the lungs and audible crepitations), nocturia, frothing of urine, and 3+ protein in his urine dipstick due to increased permeability of the glomerular capillary wall and this plus the associated hypercoagulable state suggested by a recent pulmonary embolism are all part of the nephrotic syndrome.

2. I think Mr Adams' nephrotic syndrome and increased permeability of the glomerular capillary wall is caused by minimal change disease, focal and segmental glomerulosclerosis, membraneous glomerulonephritis or membranoproliferative glomerulonephritis.

3. I think Mr Adams has had pitting edema in his legs for 2 weeks, pulmonary edema (breathlessness, dullness to percussion of the lungs and audible crepitations) and nocturia due to hypoalbuminemia.

4. I think Mr Adams has frothing of urine and 3+ protein in his urine dipstick due to proteinuria.

**Mechanisms**

The following diseases may cause the nephrotic syndrome (increased permeability of Mr Adams' glomerular capillary wall to proteins) but are difficult to distinguish without a renal biopsy:
Minimal change disease - epithelial foot processes normally on the glomerular membrane are effaced, resulting in it being more porous for proteins.
Focal and segmental glomerulosclerosis - some segments of some glomeruli are sclerosed or have hyalinosis, and all glomeruli may have podocyte effacement.
Membraneous glomerulonephritis - protein deposits of IgG cause the basement membrane to thicken.
Membranoproliferative glomerulonephritis – mesangial cells of the glomeruli proliferate causing the basement membrane to thicken.

All of the above-mentioned diseases cause the nephrotic syndrome which consists of proteinuria (>3g/dL), hypoalbuminemia, hyperlipidemia and edema. As more protein than normal is excreted in Mr Adams' urine (proteinuria/albuminuria), this shows up on his dipstick test. The urine albumin being excreted from a height through the air into the toilet bowl causes the urine to froth. Due to proteinuria, increased renal catabolism and inadequate liver synthesis of albumin, less albumin is left in Mr Adams' blood (hypoalbuminemia) and the plasma oncotic pressure drops. Thus intravascular fluid in capillaries migrates down to the lower pressure interstitium, especially in gravity dependent areas such as the lower limb (as in Mr Adams' case) causing edema. As hypoalbuminemia progressed, Mr Adams' increase in interstitial fluid is also seen in his lungs. The interstitial fluid in the alveolar spaces is heard as crepitations on breathing and dullness when percussing lung bases. This interstitial edema stimulates juxtacapillary J receptors which cause Mr Adams' sense of breathlessness as the work of breathing with "stiff lungs" when he walks up stairs becomes difficult. The redistribution of fluid into the circulation from the gravity dependent interstitium when Mr Adams is supine at night causes increased renal blood flow and urinary excretion (nocturia). The nephrotic syndrome is associated with hypercoagulable states due to deficiency in antithrombin III (it is lost in the urine) reduced amounts of protein C and or S, impaired fibrinolysis, enhanced platelet aggregation and hyperlipidemia. The fact that Mr Adams has nephrotic syndrome may have predisposed him to having a pulmonary embolus.

**Learning Issues**

Sufficient Prior Knowledge

What are the likely causes nephrotic syndrome in a 52 year old non-diabetic man?
What is the mechanism for nephrotic syndrome?
What is the mechanism for breathlessness with nephrotic syndrome?
What is the mechanism for pitting edema of the legs in this man?

New Learning Issues

What is the mechanism for Mr Adams nocturia?
How does nephrotic syndrome cause a hypercoagulable state?
What is the mechanism that explains urine frothing in the toilet bowel?

## APPENDIX N – CASE 5 (YEAR 1 2005 MOCK EXAMINATION)

An 18 year-old female student at the University of South Australia presents to the Health Service complaining of feeling very unwell, with chest pain and sweating, getting worse over 8 – 9 hours.

She had 'felt fine' yesterday, had a productive day and went to bed, feeling well, about 11.00 pm. When she awoke this morning, she did not feel as "bright" as usual.

However, she showered, dressed and ate breakfast as usual, but everything seemed to be an effort and she was conscious of a dull headache, all over her head. Even so, she decided she should attend classes and perhaps it would pass. But by 10.00 am she was feeling worse. She felt hot and her headache was worse. She took a couple of paracetamol tablets, but obtained little relief.

By midday she was feeling hot, lethargic and sweaty. She noticed pain in the left chest when she took a deep breath and felt as though she was a 'bit short of breath'. She did not feel like eating lunch, and dozed in the library.

By 2.00 pm, the chest pain had become more severe and she was sure she was getting breathless. The pain was made worse by even normal breathing now and she was aware of a dry cough, which also made the chest pain worse. She still felt hot and was sweating. She went to a class, but fell asleep.

By 3.30 pm, she had become quite ill and she was obviously breathless, even at rest. The chest pain was worse and she found that it was not so troublesome, if she held her left arm against her side and breathed mainly with her right side. She was drowsy and sweating. A friend assisted her to go to the Health Service on campus. In the waiting room, she was coughing and bringing up a small amount of rusty coloured sputum. The pain was worse and she was sweating profusely. She starts to shiver. She looks flushed and is obviously sick and breathless. She has a repetitive, irritating, painful, dry cough.

1. List below (in decreasing order of clinical importance) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
|---|---|---|
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses.

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient’s illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new learning issues that you identify for this case

# APPENDIX O – CASE 6 (YEAR 1 SEMESTER 1 2005 EXAMINATION)

Mrs Pamela Anderson, aged 47, is brought to the Emergency Department by Ambulance at 10.00 am, having been seen by her local doctor earlier in the morning. She is complaining that she is unable to stand up without feeling faint and dizzy for the last 2 hours, since she had her usual morning bowel action at 8.00 am. She had noted that she passed a large amount of dark blood, including blood clots along with bright blood with a formed motion. She has been sweaty and faint since then. She had noticed blood on her motions on 3 or 4 occasions over the last 2 months, but had attributed it to a recurrence of bleeding haemorrhoids, which had troubled her in each of her 3 pregnancies (the last of which was 11 years ago).

On questioning, she admits to having felt ‘a bit flat’ (unwell) for the last 3 months. She has been lacking in energy and noted that she tired more easily than usual. Over the last month she has noticed that she was becoming breathless carrying the wet clothes to the clothes line and carrying her weekly shopping. She has not had any chest pain. She has had no indigestion and has been eating well. Her weight is constant. She has had trouble with constipation over the years and that has been more of a problem in the last 3 to 4 months. In that time, she has also noticed several minor attacks of cramping pain in the left iliac fossa, relieved by having her bowels open. She has had no nose bleeds and has not noticed any increased tendency to bruise. Her periods have been regular, and not increased.

On examination:
She is a large woman; pale and sweaty and her skin is cool. She looks anxious.
PR is 106 bpm. JVP not raised. BP 110/70 lying; 90/60 sitting (makes her feel light-headed).
HS dual, systolic flow murmur, maximal at the base.
Chest: Clear, no crepitations.
Abdomen: No masses. A little tender in the left iliac fossa.
Rectal examination: Two small haemorrhoids –neither are ulcerated or bleeding. No masses felt.
Small amount of firm faeces palpable in rectum; dark blood on the examining finger.

1. List below (in decreasing order of clinical importance) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
|---|---|---|
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient's illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new **learning issues** that you identify for this case

## APPENDIX P – CASE 7 (YEAR 1 SEMESTER 2 2005 EXAMINATION)

Ms Cecilia Watson, aged 46, Tax Consultant
Ms Watson is brought by ambulance to the Emergency Department at 10.30 pm. She is complaining of severe generalised abdominal pain and vomiting. The pain came on suddenly about an hour ago. It was very severe from the beginning and is constant in intensity. It did not radiate through to the back, but at the onset she was conscious of pain in her left shoulder tip region. She felt severely nauseated and unwell from the onset and soon began to vomit.

This appeared to be mostly partially digested food. She did not think there was any blood in the vomitus. She felt dizzy and had to lie down. She has noted that the pain is worse when she moves, so she prefers to remain very still, lying flat. She has been sweating profusely since the pain came on.

She has never experienced anything like this previously. Her general health has been good. She has been under additional stress at work for the last few months and has been suffering from indigestion as a result. The indigestion takes the form of burning pain in the epigastrium, and is more severe when she misses lunch. Recently it has been waking her at night. She has been taking some proprietary indigestion remedy she bought at the Pharmacy. She has been too busy to see her local doctor. Her bowels are regular and she has had no urinary problems. Her periods have been regular and unchanged.

Her weight has been constant. She is not conscious that any particular foods make the indigestion worse, but avoids tomatoes and onions. She has no trouble eating fatty foods. She does not suffer from reflux. She had a snack for lunch about 3.00 pm and then worked until 8.30 pm tonight. She was preparing a meal for herself when the pain came on. She used to play golf twice a week, but had to stop, about 18 months ago, on account of low back pain. The back pain still recurs, from time to time, despite regular use of anti-inflammatory medication (NSAIDs) prescribed by her local doctor, whom she last visited 3 months ago for a repeat prescription.

On examination:

An anxious sweating woman, of slight build, lying very still on her back, in obvious pain. Any movement makes the pain worse.

Her skin is moist and cool. Pulse 108 bpm; BP 100/70, lying flat (not done sitting up on account of pain).

Abdomen: Flat; very tender to even gentle palpation - "all over". Abdomen is rigid throughout. Release tenderness is present. Bowel sounds difficult to detect.

X-Rays of the abdomen, in erect position, demonstrate "air under both diaphragms".

The doctor tells the patient it is likely she has a ruptured abdominal viscus, for which she will need immediate surgery.

1. List below (in **decreasing order of clinical importance**) the major data points relating to this patient's illness and indicate briefly why you think each point is significant. Indicate the hypothesis/es for which you have used this piece of data.

| Data Points | Significance | Used in hypothesis number |
|---|---|---|
| | | |

2. Set out in reducing order of likelihood (most likely first) up to four (4) hypotheses, that you think best explain this patient's illness.

3. For EACH hypothesis, indicate (with brief reasons for your conclusion) which data support, and which detract from, the hypothesis.

4. Set out the briefly the mechanism which you consider best explains each of your hypotheses

4. Continued

5. LIST up to five (5) areas of knowledge, which you identify as being of major importance to understanding this patient's illness, and about which you feel you have sufficient prior knowledge, or need only minor revision.

6. LIST up to four (4) of the most important new **learning issues** that you identify for this case

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