Clinical Reasoning in Dental Students: A comparative cross-curricula study

Ebtihaj Talal Nafea, BDS, MMedSci

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Abstract

Clinical reasoning is a skill required by all health professionals in managing patients. Research in clinical reasoning has come mostly from medicine and nursing, less from dentistry. The effect of curriculum on the development of clinical reasoning is still not well understood. Moreover, no research has been conducted to understand what clinical reasoning means to students and what educational strategies are valued by them. The aim of this research is to explore the effect of different educational strategies in different dental schools on clinical reasoning and to discover how students perceive clinical reasoning.

Final year students from four different dental schools participated in the current research; a school using an integrated curriculum with conventional teaching, a school using Problem Based Learning (both from the UK) and two Saudi Arabian dental schools; a school using a traditional curriculum and a school using an integrated curriculum. Both UK schools participated in both studies, whereas each one of the Saudi Arabian schools participated in a different study. The research used both quantitative and qualitative methodology. An innovative clinical reasoning test measured final year students' skills. An interview captured their own understanding of clinical reasoning and its acquisition plus they 'talked through' a clinical problem, using a 'think aloud' technique. Thematic analysis was used to analyse the transcripts of the recorded interviews. Results obtained were related to curriculum structure.

The results indicated that the effect of curriculum structure, unlike teaching and assessment strategies, appeared to be minimal in final year students. Unfamiliarity with the term clinical reasoning was common in students. Students from different schools used different strategies to reason when discussing clinical vignettes. Different behaviours seemed to be affected by cultural factors.

This research contributes to a greater understanding of how students learn, understand and apply dental clinical reasoning which hopefully will improve educational practices in the future.

Dedicated to my husband Waleed, my parents and my children Mawaddah and Khalid

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'*Who ever receive a favour should pay back for it, and if he couldn't, he should at least acknowledge it'* (an interpreted saying of Prophet Muhammad peace be upon him)

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BDS	Bachelor of Dental Surgery
CIP	Comprehensive Integrated Puzzle
CRP	Clinical Reasoning Problems
CTT	Classical Test Theory
DTP	Diagnostic Thinking Processes
DTI	Diagnostic Thinking Inventory
EBL	Evidence Based Learning
EndoDB	Endodontic Decision Board
H-D	Hypothetico-deductive
IBL	Inquiry Based Learning
IRT	Item Response Theory
KAU	King Abdulaziz University
KFP	Key Features Problems
MCQ	Multiple Choice Question
OSCE	Objective Structured Clinical Examination
PMP	Patient Management Problems
SAQ	Short Answer Question
SA	Saudi Arabia
SCT	Script Concordance Test
TDS	Test of Diagnostic Skills

1 Chapter 1: Introduction

'Are those who know equal to those who know not?' (A translated verse from the Holy Qur'an)

1.1 Introduction

Decision-making is a natural human activity. It has different meanings for different individuals according to their specialities. In the case of a fire-fighter, a prompt decision has to be made for the purpose of saving life. In business, however, extensive studies have to be conducted and tested in order to face challenges in the market (Klein and Klein, 1993). In general, decisions are based on the individual's assessment of the benefits of choices modified by personal preference, the probability of possible outcomes, and the assessment and avoidance of any risk (Stempsey, 2009). However, in this project clinical decision-making will be treated as the process used by health professionals in order to manage their patients. Clinical reasoning is a term widely used to refer to the clinical decision making in the health professions. It can be defined as "*a complex, multidimensional, recursive process that uses formal and informal strategies to gather and analyse patient information, evaluate the significance of this information, and determine the value of alternative actions*" (Simmons, 2003).

The importance of clinical reasoning has been extensively highlighted in all health disciplines as it is widely considered a critical skill and a central component of a health professional's competence in managing patients' care. Although the term clinical reasoning is widely used in most medical and dental curriculum documentation, it is rather a complex process especially if attempts are made to understand its meaning and formulate specific evaluation tools (Norman, 2005, Higgs and Jones, 2008a). Research in clinical reasoning has come mostly from medicine and nursing with less attention devoted to clinical reasoning in dentistry (Maupome et al, 2010). Despite the effort made, research from other health disciplines cannot be simply applied to dentistry because the nature of clinical reasoning for dentists differs from that of, for example, a general medical practitioner. This is also true for other health professions, yet it is not always clear how this process is different. This fact reflects our limited understanding of the multiple factors used by clinicians to negotiate and resolve a clinical problem. What is clear about clinical reasoning is that it is considered as a core competency for all healthcare professions with variations and specifications attached to each health discipline (Khatami et al., 2008b).

In dentistry, clinical reasoning is perceived as a complex process with limited interpretation of its nature in the literature. Currently there is a repeated call to involve interpretive approaches to studies of clinical reasoning in dentistry in order to uncover the mystery associated with it. In addition, it has been argued that the type of undergraduate curriculum has an impact on the level of clinical reasoning in dental students. This impact of the undergraduate curriculum on the development of clinical reasoning has been studied, although sparsely, in the medical and dental literature (Eva, 2005). However, the results were inconclusive and there are controversial views of the role that the curriculum may play in this regard (Patel et al., 1989, Patel and et al., 1991, Sefton et al., 2008, Schmidt et al., 1996, Goss et al., 2011). Some studies suggested a minimum effect of the curriculum on the development of clinical reasoning while others have emphasised the role of the undergraduate curriculum on the level of clinical reasoning skills development. Furthermore, many of the studies conducted to find the impact of the curriculum on the development of clinical reasoning were focussed on comparing the traditional curriculum with only one type of non-traditional curriculum, namely the Problem-based learning (PBL).

We cannot ignore other types of the undergraduate dental curricula which are widely being used in dental education *e.g.* the integrated curriculum. With the current status of research there is still a need to conduct more studies in order to understand what strategies could help students to develop their reasoning skills. There is also a need to find out what factors can affect the development of this important skill (Groves, 2002, Anderson, 2006).

To our knowledge no study has yet been conducted to investigate the effect of culture on the characteristics of the clinical reasoning process in dental students. Furthermore, most of research in clinical reasoning has focussed on studying this phenomenon with no mention of its meaning to the participating individuals. We think that knowing what clinical reasoning means to the students and enhancing their awareness about it could be the first step in enhancing its development.

The aim of the present research project is therefore to address this gap in the literature and add to the body of knowledge within this field of research. We aimed at exploring the impact of different educational strategies used among different types of dental schools on the development of clinical reasoning. We also studied the differences in the clinical reasoning process by undergraduate dental students from four different curriculum models and two cultures. Firstly, analysis of the four participating dental schools' curricula was conducted using well known frameworks (SPICES model and the Integration Ladder). Secondly, two complementary studies were carried out to explore an understanding of the curriculum effect on clinical reasoning development in dental students.

The first study involved creating an innovative tool to assess clinical reasoning. This tool, the Clinical Reasoning Test (CRT), was developed by combining well known methods of assessment for clinical reasoning in an attempt to combine their advantages.

After validating our CRT, the process and the product of clinical reasoning were quantitatively analysed in order to study the differences between three cohorts of final year dental students coming from a traditional curriculum presented by King Abdulaziz University in Saudi Arabia; an integrated curriculum presented by The University of Birmingham and a PBL curriculum presented by The University of Manchester both from the UK.

The second study was directed towards understanding the meaning of clinical reasoning from the students' viewpoints, their perception of how clinical reasoning can be taught, and their evaluation of the benefits of the different strategies and methods in fostering the development of this critical skill. Differences between the reasoning process and strategies were qualitatively analysed in order to study the effect of culture and the different curriculum models involved in the study through discussing clinical vignettes. Semi structured in depth interviews were conducted with samples of final year undergraduate dental students coming from three schools namely the Dental School at The University of Manchester, the Dental School at The University of Birmingham in the UK and the Dental School at Taibah University from Saudi Arabia. The following section will describe research paradigms in general and the philosophical approach embraced in the current project.

1.2 Research paradigms

Medical education research is argued to have a complex nature. Some authors assert that it has a strong relationship to social science and must, therefore, be critically engaging with questions of research philosophy. Focussing attention on its philosophy is a hall-mark of this type of research (Lingard, 2007). On the other hand, there are authors who believe that medical education research should be treated in a positivist empirical way which is central to medical research.

Table 1:1: The common paradigms used in medical education research, and their main characteristics regarding ontology, epistemology and methodology, source: (Bunniss and Kelly 2010).

	Positivism	**Post-positivism**	**Interpretivism**	**Critical theory**
Ontology: What is the nature of reality?	Reality is static and fixed The world is ordered according to an overarching objective truth		Reality is subjective and changing There is no one ultimate truth	Reality may be objective but truth is continually contested by competing groups
Epistemology: What is the nature of knowledge?	Objective, generalisable theory can be developed to accurately describe the world Knowledge can be neutral or value-free	Objective knowledge of the world is not necessarily fully accessible Seeks to establish 'probable' truth	Knowledge is subjective There are multiple, diverse interpretations of reality There is no one ultimate or 'correct' way of knowing	Knowledge is co-constructed between individuals and groups Knowledge is mediated by power relations and therefore continuously under revision
Methodology: What is the nature of the approach to research?	The aim is to discover what exists through prediction and control Theory is established deductively Uses scientific method to develop abstract laws to describe and predict patterns Looks for causality and fundamental laws	Seeks to develop knowledge through the falsification of hypotheses Emphasis on well-defined concepts and variables, controlled conditions, precise instrumentation and empirical testing	Focus on understanding Uses inductive reasoning Meaning is constructed in the researcher–participant interaction in the natural environment Gathers diverse interpretations (e.g. grounded theory, ethnography)	Focus on emancipation Research is used to envision how things could change for the better Seeks representation of diverse and under-represented views Characterised by continual redefinition of problems and cooperative interaction (e.g. action research)
Methods: What techniques can be used to gather this information?	Tends to use quantitative methods, often including statistical testing of hypotheses (e.g. randomised controlled trials, questionnaires)	Quantitative and qualitative methods: systematically gathered and analysed data from representative samples (e.g. surveys, interviews, focus groups)	Tends to use qualitative methods to capture various interpretations of a phenomenon (e.g. naturalistic observation, interviews, use of narrative)	May use both quantitative and qualitative methods, usually in a participatory way Often uses iterative research design (e.g. case studies, focus groups, participant observation)

Research philosophy involves describing the paradigm underpinning research. Paradigms can be defined as "*sets of beliefs and practices, shared by communities of researchers, which regulate inquiry within disciplines. The various paradigms are characterised by ontological, epistemological and methodological differences in their approaches to conceptualising and conducting research, and in their contribution towards* *disciplinary knowledge construction*" (Weaver and Olson, 2006). There are four types of paradigm commonly used in medical education research.

Table 1:1, (above), illustrates these paradigms and the differences between them with regards to ontology, epistemology and methodology. As will be discussed in Chapter 5, positivism has been, for a long time, the paradigm underpinning most of medical education research. However, there is a recent shift towards involving more qualitative research in medical education.

Bunniss and Kelly (2010) highlighted the importance of understanding and mentioning the research paradigm in methodology, as follows: "*research methodology is not simply about data collection strategies, but, more importantly, that it addresses the philosophical beliefs that determine the nature of the research design. Articulating these underlying assumptions is central to the research task if we are to be able to critically engage with the findings*". Although there are different paradigms embraced in medical education research, the quality of any research should be reflected in the integrity and transparency of its philosophy and methodology rather than the superiority of its paradigm.

1.2.1 Pragmatism

Morgan (2007) has argued that research in general cannot be purely qualitative or quantitative in nature, and moving between data collection and the theory behind it is not always of a clear cut nature. It is also widely assumed that researchers cannot be purely objective or purely subjective when conducting research. There is always a mixture of both. Therefore, pragmatism has developed in response to paradigm incompatibility in real world research (Maudsley, 2011).

Pragmatism is a noun which, according to the Cambridge dictionary, means dealing with a particular problem in a realistic way without obeying fixed known ideas, rules or theories (Cambridge University, 2008). The use of the pragmatic approach is familiar when qualitative and quantitative methodologies are combined in a sequential manner. In this case the results of one methodology inform the other (Morgan, 2007), but other combination manners are also possible. It is considered a *pluralistic* approach in which both methodologies are combined rather than being contrasted and compared (Schifferdecker and Reed, 2009). Incorporating a pragmatic approach is not new in medical education research (Maudsley, 2011). Pragmatism is the paradigm underpinning the current research as it will use mixed-methods, both quantitative and qualitative. A summarised explanation of its main concepts is presented below followed by reasons for its implementation in the current research.

Pragmatism is a mixture of deductive and inductive approaches to research, (see Table 1:2). This paradigm uses an *abductive* reasoning of moving back and forth between deductive and inductive approaches.

Table 1:2: The main characteristics and the differences between qualitative, quantitative and pragmatic approaches to research, source: (Morgan, 2007).

	Qualitative Approach	Quantitative Approach	Pragmatic Approach
Connection of theory and data	Induction	Deduction	Abduction
Relationship to research process	Subjectivity	Objectivity	Intersubjectivity
Inference from data	Context	Generality	Transferability

Another characteristic of the pragmatic approach is the mixture between subjectivity and objectivity in a process known as *inter-subjectivity*. This paradigm agrees with the objectivists approach in that there is one real wold (external reality), but different interpretations (subjectivity) of this world are also allowed, reflecting the subjectivists approach (Morgan, 2007, Maudsley, 2011).

The third characteristic presented in Table 1:2 is the term *transferability*. This represents a point in the middle between the two extremes characterising qualitative and quantitative approaches. Pragmatism argues that the created knowledge can never be generalised nor purely context dependent. Results of pragmatic research can be transferred and applied in another context provided that we are aware of the factors affecting these results. Furthermore, the pragmatic approach is characterised by being driven by the research question rather than following established theory *per se* (Maudsley, 2011). In other words this approach can be defined as being problem-centred.

A pragmatic approach was chosen for the current research for many reasons. Firstly, we believe that studying a complex multidimensional process such as clinical reasoning would require rigorous analysis of data going back and forth between inductive and deductive approaches without restrictions. We also believe that clinical reasoning is a real world phenomenon that can be interpreted differently by researchers. More explanation of the different interpretations of clinical reasoning will be provided in the next chapter. Our research is argued to be real-world practice oriented, as we aim to develop knowledge that can be used by dental schools to enhance the development of clinical reasoning in their undergraduate students. We propose to do so by striving to supply explanations to our research questions. However, we do not claim the generalizability of our results in different contexts and situations. Instead we think that the results of the current research could help to add more clarification to the phenomenon of clinical reasoning which is commonly perceived as being mysterious.

The results of the current research were created by combining both qualitative and quantitative methods in a pluralistic design in which a conclusion was derived from two different studies. This research is also problem-centred as we assume that clinical reasoning (as an external reality) can be investigated following the answering of the research questions we propose. One of our studies aimed at studying the impact of the different curriculum models on the development of clinical reasoning. The results of this study suggested a minimal effect of the type of curriculum. We also decided to carry out our qualitative study to get a deeper understanding of the curriculum effect, and we found interesting differences related to curriculum models and cultures. We also added another aspect to studying clinical reasoning in that we aimed to understand what students think of this skill and its development, aiming to add to the body of knowledge in this regards. Finally, findings of both studies are discussed in order to answer the proposed research questions.

We certainly agree with the pragmatists' view of implementing the best possible methods to answer the research questions in order to develop new pieces of knowledge. The following section will outline the methodological choices and the research questions.

1.3 Methodology

The present research adopts a mixed-methods methodology. This methodology involves combining, relating, integrating and associating qualitative and quantitative methodologies in one research. The use of this methodology in medical education research has been increasing in the last decade (Schifferdecker and Reed, 2009, Maudsley, 2011). One of the purposes for using this methodology is to complement findings and add more value to the research in order to clarify the results and enhance the description and application of the research findings. It can also be used to expand the research questions by increasing the scope of the inquiry (Greene et al., 1989). Different designs of mixed methodology have been identified in medical education research. One of these designs is the *explanatory model*. In this model a qualitative study is conducted in order to clarify the results obtained from the quantitative methods. Data are then combined to complement each other and to add more clarification to the results (Schifferdecker and Reed, 2009).

Mixed methodology suites the aim of the current research in that it provides more clarification of a complex phenomenon rather than the isolated use of quantitative or qualitative methodologies (*ibid*). Clinical reasoning is a complex process and studying its nature could be enhanced by using mixed methodology. Moreover, clinical reasoning is a multidimensional and multifactorial construct that is difficult to measure by direct observation. Furthermore, contrasting views about the best model to describe this phenomenon exist in the literature and there is no consensus about the best method to evaluate its level (Eva, 2005). As will be described later, studying the effect of different curriculum models on the development of clinical reasoning in medical and dental students has produced contradictory results.

The use of mixed methodology allowed us to add more depth to our findings and expanded our inquiry about the relationship between the undergraduate curriculum model and the understanding and characteristics of clinical reasoning skills in dental students. We also were able to draw on some cultural and language effects on the characteristics of the students' reasoning. Moreover, the meaning of clinical reasoning was described from the students' point of view. Their views about the effective strategies to promote the development of clinical reasoning skills were qualitatively analysed. As a result the scope of the research has expanded. Figure 1:1 below outlines the integration of quantitative and qualitative methodology in the current research.

Paradigm	Pragmatism	
	Study 1	Study 2
Aim	Assessment of clinical reasoning level in final year dental students using clinical reasoning test (CRT) Comparing the results obtained from students at different curriculum models	Finding what clinical reasoning means to students and how it may develop Comparing the characteristics of clinical reasoning of students at different dental schools
Methods	Mainly quantitative & qualitative analysis of one question in the test (Q22)	Qualitative analysis of semi-structured interviews & quantitative analysis of the interviews' time
Results		

Figure 1:1: Research paradigm and methodology showing mixing quantitative (study 1) and qualitative (study 2) methods in order to expand and clarify the research scope of understanding the impact of different models of curricula on the development of clinical reasoning in undergraduate dental students.

1.4 Research aim and questions

1.4.1 Research aim

The current research aims at understanding the relationship between the different models of dental curriculum at the undergraduate level and clinical reasoning understanding in final year dental students. This was done through comparing the different results and characteristics of students' clinical reasoning at different dental schools. This aim could help in suggesting and understanding the effectiveness of different educational strategies to foster the development of clinical reasoning skills.

1.4.2 Research questions

Table 1:3 illustrates the overall questions raised by the research aims, the instruments used and data collection procedures for each question, with reference to specific chapters covering them in this thesis. Research questions were raised in an attempt to address gaps in the literature regarding clinical reasoning in dentistry and the effect of the curriculum on its development. Questions were also raised by the researcher herself being a dentist and teaching staff interested in dental education at a newly established Saudi dental school.

1.5 Rigor and quality considerations

High quality research should be "cogently *developed; competently produced; coherent with respect to previous work; important and ethical; and comprehensive*" (Niglas, 2004). In the current research we have striven to meet these criteria. Criteria for rigor and quality will be presented for each study in the methodology section described in Chapters 4 and 5.

1.6 Purpose and structure of this thesis

The current thesis aims to contribute to the understanding of the curriculum impact on the level and quality of clinical reasoning in dental students. This has been achieved by studying the understanding and characteristics of both the process and the products of clinical reasoning, and relating them to the different characteristics of the undergraduate curriculum including the curriculum model, clinical exposure and assessment strategies used at different dental schools.

Chapter two will review the current literature on clinical reasoning. Chapter three will discuss the curriculum effect on clinical reasoning development. It will also discuss the context in which our studies took place. Four different undergraduate dental curricula were analysed. Chapters four and five will present our quantitative and qualitative studies, respectively, in self-contained sections. We decided to discuss each study in separate chapters to make it easy for the reader to relate and connect context, methodology and findings especially because of the different samples and methods used in each study. In chapter four a discussion of the creation and validation of our purposely designed CRT will be provided. Results of this test will be discussed and the differences between the cohorts of students will be presented. Chapter five will present our qualitative study. It will describe different views of students about clinical reasoning and its development and the differences between three cohorts of students, at different curricula, when they discussed clinical vignettes.

The results of each study will be presented in the same chapter discussing each of them. We will also revisit and combine these findings in chapter six. We will also provide an overall discussion of the findings, implications for curriculum development, further research and conclusion.

Table 1:3: Research design overview

Aim	Research method	Research questions (summary)	Instrument/tool	Data collected
Understand the impact of different types of dental curriculum on the development of clinical reasoning	Identifying the characteristics of study context: analysis of the different curriculum	• How have the effect of curriculum on clinical reasoning been reported in the literature? • What are the characteristics of regulatory bodies in the two countries? • What are the similarities and differences	Evaluation of the curriculum using SPICES and Integration Ladder models	Publicly available primary resources, curriculum documentations and personal contact with gatekeepers

	Chapter 3	between the four types of curriculum in their models, aims, strategies, assessment, clinical exposure, and clinical reasoning opportunities?		
Understand the effect of the type of different curriculum on the level of clinical reasoning	Cross-sectional comparative study(quantitative) Chapter 4	• How can clinical reasoning be assessed? (Chapter 2) • How can we create a valid and reliable test combining the elements of	Data collection tool: Clinical Reasoning Test (CRT) Quantitative data analysis tool: SPSS 19.0 software &	Answers to online CRT using Survey Monkey ®

		established clinical reasoning tests? • What are the differences between the results of different cohorts of student, and how can they be related to their curriculum types? Or other factors *e.g.* gender & knowledge	thematic analysis of one question in the CRT	
Finding out what students think of clinical reasoning, and how their	Qualitative study Chapter 5	• What does clinical reasoning mean to students?	Semi-structured in depth individual interviews	Thematic analysis of transcripts

different types of curriculum affect their clinical reasoning process		• What do they think of clinical reasoning development and the effective teaching strategies? • How does their reasoning process and strategies differ? • Is there any factors affecting their reasoning characteristics?		QSR NVivo 10® software to organise themes

2 Chapter 2: Clinical Reasoning

'Over all those endowed with knowledge is a more-knowing'

(A translated verse from the Holy Qur'an)

Chapter outline

The aim of the present research is to understand the educational effect of the different models of curricula on the development of clinical reasoning in dental students. As a first step, it is important to review the available literature on clinical reasoning in order to gain an understanding of the phenomenon and to inform questions and directions followed in the current research. This chapter explains the nature of clinical reasoning (including concepts and models), its development, factors affecting the acquisition of this skill, its teaching, its assessment and, finally, the status of clinical reasoning research in dentistry.

2.1 The nature of clinical reasoning

Despite the advances in clinical reasoning research in medical education there is still a lack of consensus about the best way to define clinical reasoning and the best way to teach or assess this important skill (Durning et al., 2013).

The complexity of the process of clinical reasoning has contributed to the use of different epistemological and theoretical frameworks in order to define, understand and describe this term by medical educators. The contrasting views of the researchers are reflected in the different definitions and frameworks provided for clinical reasoning in the literature. These varied views can be related, whether knowingly or not, to two main epistemologies and their related theories, as will be discussed later.

2.1.1 Definitions of clinical reasoning

Clinical reasoning is a very complex and poorly understood process during which a health professional works through a clinical problem to find solutions for the case, handling patient-related and context-related factors (van den Broek et al., 2012, Kay and Blinkhorn, 1996). During this process the professional is striving to choose a proper diagnosis out of many possibilities by selectively investigating information. It also includes the choice of treatment options available bearing in mind the resources and the other factors that affect his/her choices.

Multiple definitions have been produced for clinical reasoning in the literature with a spectrum of complexity associated with these definitions. These definitions may potentially reflect the varied theoretical stance of their creators. As mentioned earlier, any definition of clinical reasoning can be consciously or unconsciously referring to a specific theoretical framework and epistemology.

Clinical reasoning, medical problem solving, diagnostic reasoning, and decision-making are different terms used to describe the process of *how a clinician makes decisions*. These terms have been used synonymously in the literature, and we may use them similarly in this research for simplicity. However, some researchers separate these terms *e.g. "decision making can be considered as the product and/or the process of clinical reasoning"* (Ajjawi and Higgs, 2008).

The process of clinical reasoning can be simply defined as the sum of thinking and decision-making processes associated with clinical practice. It is widely considered as a critical skill and central component of competence in the health professions if not the most important part of patient's care (Higgs and Jones, 2008b).

The term clinical reasoning or one of its multiple synonyms always appear in the list of objectives stated by most medical schools, licensing organisations and speciality societies (Higgs and Jones, 2008a, Norman, 2005, Kassirer et al., 2009, Patel et al., 2004). However, when it comes to understanding, describing and formulating an appropriate definition for clinical reasoning it is rather a complex multifactorial process (Neufeld et al., 1981). In other words, despite the wide use of the term in most medical schools documentation, it is usually not a straight forward procedure to understand its meaning, or to formulate instructional approaches or assessment tools (Norman, 2005, Higgs and Jones, 2008a).

One of the extensively quoted definitions is the one formulated by Higgs in 2006 (Higgs and Jones, 2008a). He described clinical reasoning (or practice decision making) as "*a context-dependent way of thinking and decision making in professional practice to guide practice actions. It involves the construction of narratives to make sense of the multiple factors and interests pertaining to the* *current reasoning task. It occurs within a set of problem spaces informed by the practitioner's unique frames of reference, workplace context and practice models, as well as by the patient's or client's contexts. It utilises core dimensions of practice knowledge, reasoning and metacognition and draws on these capacities in others. Decision making within clinical reasoning occurs at micro, macro and meta levels and may be individually or collaboratively conducted. It involves meta skills of critical conversations, knowledge generation, practice model authenticity and reflexivity"*.

The complexity of clinical reasoning comes from the nature of the task facing both novices and experts in which the clinician needs to process multiple variables, contemplates the various priorities and negotiate the interests of different participants in the decision-making process using his/her advanced knowledge base in the context of professional ethics and community expectations (Higgs and Jones, 2008a).

According to Higgs, clinical reasoning should be considered as a lived phenomenon, an experience, rather than simply describing it as a process. To look deeply into this phenomenon, clinical reasoning constitutes core dimensions and other additional components, (see Figure 2:1). Knowledge, cognition and metacognition serve as basic (core) components. **Knowledge** is of paramount importance in clinical reasoning. It refers to the strong discipline-specific knowledge base used by the clinician whether it comes from theory and research (propositional) or the non-propositional knowledge, which comes from professional and personal experience. Knowledge is crucial for sound and responsible reasoning process.

The second core dimension is **cognition** or reflective enquiry. Specific skills such as analysis, synthesis and evaluation of collected data are utilised to process the presented clinical data against the clinician's existing knowledge base in consideration of the patient's need and the clinical problems.

Metacognition or reflective self-awareness can serve as a bridge between knowledge and cognition. Metacognition is defined by Barrows and Garfield as "*a voluntary, conscious, and self-monitoring act of thinking*" (Barrows and Pickell, 1991). It enables clinicians to identify limitations in the quality of the obtained data, inconsistency or unexpected findings, making them to continually monitor their reasoning practice seeking errors and credibility. It also helps them to identify any limitations in their knowledge and skills directing them to take further actions.

There are other additional dimensions for clinical reasoning. The role of the client in the reasoning process is known as mutual decision making. The reasoning process could also be affected by the situation or the environment of the context with which the clinician is interacting. Finally, the nature of the clinical case can also influence the process of reasoning.

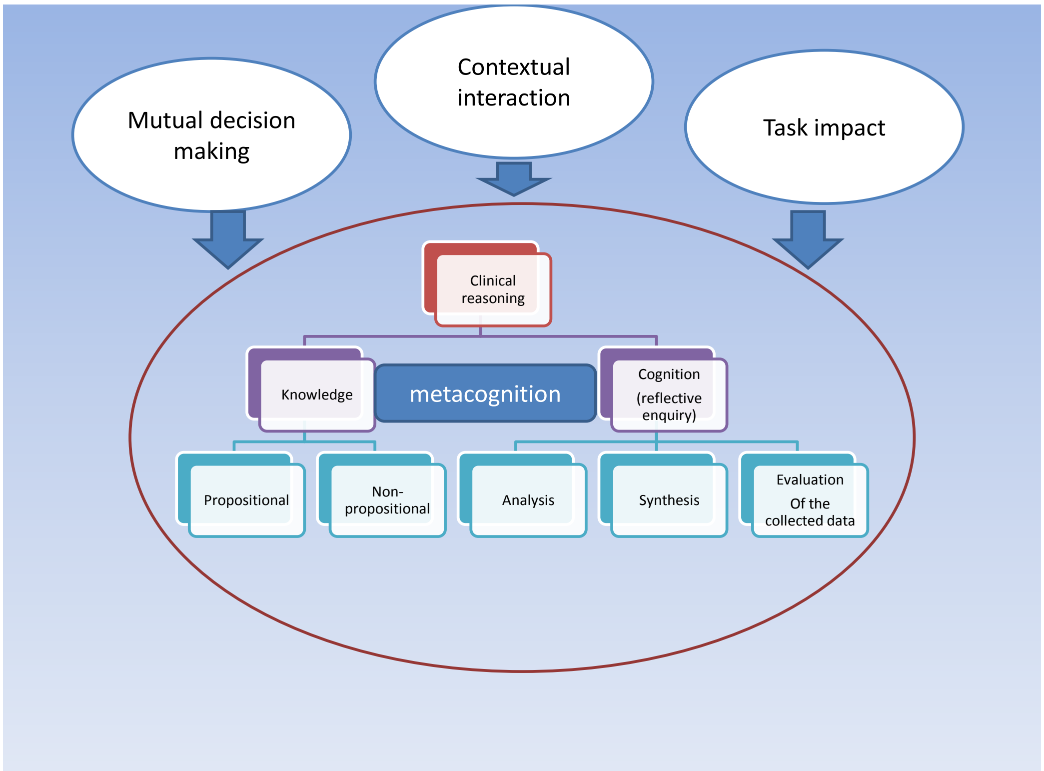

Figure 2:1: The components of clinical reasoning as suggested by Higgs. Knowledge, cognition and meta-cognition constitute the core components of clinical reasoning. Other factors may also influence it, such as patient-related (mutual) factors, characteristics of the task and the environment.

Another definition of clinical reasoning referred to it as "*the cognitive process by which the information contained in a clinical case is synthesized, integrated in with the physician's knowledge and experience, and used to diagnose and manage the patient's problem*" (Newble et al., 2000). This definition, in contrast to the previous one, only focuses on the process of clinical reasoning stressing on the cognitive process taking part in a physician's mind.

There is a long list of definitions and interpretations to clinical reasoning in different health professions and presenting them would be beyond the focus of the current research. The definitions presented above were only used to reflect the diversity of explanations proposed for this process. In conclusion, providing a definition that best reflects this skill, process or phenomenon could be impossible because of the complexity attached to it. The challenges also include a long list of variables and factors affecting it. These factors will be discussed later in this chapter.

In the following section, a description of the two main epistemological views will be presented. Associated theories will also be described. This description is followed by the related different conceptual frameworks provided for clinical reasoning.

2.1.2 Epistemological considerations

In order to get an understanding of the nature of clinical reasoning, it might be helpful to discuss the epistemological and theoretical considerations first. Epistemology is a branch of philosophy that involves studying knowledge including its nature, scope, construction, and limitations. There are two main contrasting epistemological views: *objectivist* and *constructivist*. These different perspectives to epistemology have shaped the description of the learning process involved in different skills, including clinical reasoning, the educational strategies required and consequently the assessment involved. They also have an impact on the understanding and definitions provided for clinical reasoning.

The **objectivist** (logical/positivist) perspective considers that there is only one single set of truths that can be discovered. In this perspective, knowledge is seen as truths that the teacher should instruct learners to acquire by providing the required knowledge, with little importance ascribed to the learner’s own experience. In this view, variables are seen as traits that an individual might or might not have. In other words, clinical reasoning may be treated as a trait and the level of this skill should be constant and independent on factors such as physical location (Durning et al., 2013).

However, for **constructivists,** knowledge is thought of as a complication of human made constructions (Raskin, 2002). Thus teaching involves providing learners with relevant experiences so that they can construct the meaning themselves. Knowledge is acquired through interaction of the individual with his/her environment or other individuals. The key point of learning in this view is to provide the learner with experience rather than only static facts (Dennick, 2008).

In order to get a better understanding of how clinical reasoning could be taught and assessed, an important question should be discussed in the first place: *is clinical reasoning a construct with only one truth which can be taught in one way or is it a construct that depends on the situation and/or the individual who is constructing, or a combination of both?*

The epistemological point of view we adopt not only influences our understanding of the teaching and assessment of clinical reasoning; it also affects our expectations and perception of errors. For example if the skill of clinical reasoning is considered from an objectivist point of view, then we should consider it as a trait that an individual either possesses or not. In this case teaching would be directed towards providing a way of teaching the facts behind this trait. In this view one would expect clinical reasoning to be stable in all conditions and situations for an individual clinician. If there would be any variation in the reasoning ability of an individual on different occasions, this would be considered as an error.

However, the opposite can be applied to the constructivist epistemology which sees clinical reasoning as a result of continuous interaction between the clinician and many factors, and this skill varies in different conditions (Durning et al., 2013).

Theoretical views that educators use to understand the learning process have emerged from these two epistemological viewpoints. These theories are: behaviourism, information processing theory, situativity theory and psychometric theory. The following section discusses the main characteristics of the different theories suggested to describe the process of clinical reasoning. Please refer to Table 2:1 for a summary of the main differences between theories shaping our perception of clinical reasoning.

2.1.3 Theoretical concepts

The epistemological concepts described above lead towards different theories for the clinical reasoning learning process. These theories not only help us to understand learning by students, but also affect the educators' view of the strategies, tools and process that should be used for the assessment and teaching of clinical reasoning.

2.1.3.1 Behaviourist theory

This theory is based on the objectivist view point. Clinical reasoning in this view only incorporates what can be seen in clinical settings, omitting clinicians' thoughts and emotions. However, there is a spectrum in this theory and the view just described is that of the strict behaviourists. Also in this theory, clinical reasoning can be learned through behaviour modification. Thus a student can learn to reason following the receipt of rewards or punishments directed towards him/her or even towards other students. Figure 2:2 presents a diagram for this process.

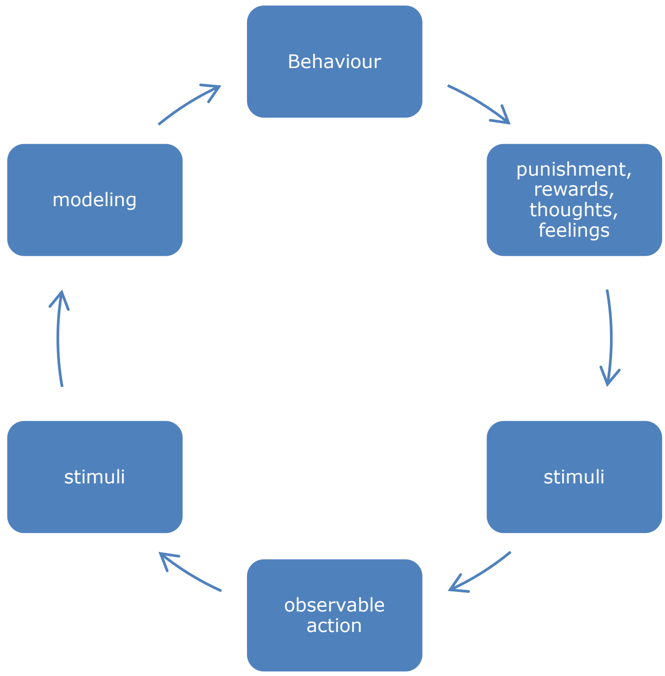

Figure 2:2: Behaviourist view of the learning process. Learning takes place by behaviour modification. Punishment and rewards act as stimuli for behavioural changes. This process is continually taking place and leads to modifications of the learner's behaviours.

Although this theory is not a major guiding force for learning in medical education some of its components still exist in situations where the assessment focusses on measuring outcomes (behaviour) rather than cognitive processes *e.g.* competency-based assessment. It is also prominent in most medical and dental schools' curriculum documentation and objectives when the focus is directed towards achieving a list of competencies (behaviours) rather the learning process required for that. One of the deficiencies associated with behaviourism is that it is only applicable in action *i.e.* clinical settings, being deficient when it comes to describe the reasoning process in novices who are not yet experienced in clinical situations (Durning et al., 2013).

2.1.3.2 Information processing theory

This is the prevailing theory in current clinical education and most of the definitions and explanations of clinical reasoning process actually follow this model. This theory was first developed by Newell and Simon in 1972. Information processing theory describes the interaction of a problem solver with the knowledge and experience which is organised in his/her mind. This view has produced some of the important explanations of the reasoning process in the literature, which include: script theory, dual-process theory and cognitive load theory.

Illness scripts have been widely suggested to explain the clinical reasoning process by which a clinician associates and formulates the signs and symptoms of different conditions. The presence of any element can trigger a specific script. The development of illness scripts is suggested as a step in the development of clinical reasoning in medical students towards gaining expertise. This will be further described below, in the *development of clinical reasoning process* section.

Dual process theory comprises *analytical* and *non-analytical* reasoning. In this theory, clinical reasoning can be one of the two types or simply a combination of both analytical and non-analytical reasoning. Analytical reasoning on the one hand is a process by which a clinician is thinking and analysing information in order to formulate possible diagnoses or treatment options. The hypothetico-deductive model of reasoning is a suggested example of reasoning, which follows this view, in medical students and less experienced clinicians. Experts can also use this strategy to deal with difficult clinical cases. Non-analytical reasoning on the other hand is a fast process by which experts can easily reason through usual clinical cases. It also includes the use of pattern recognition. Further descriptions of these reasoning processes are provided below in section 'S*ystem 1 Vs system 2'* on page 48

Cognitive load theory is another explanation related to information process theory. As proposed by Newell and Simon (1972), an individual functions as an information-processing system having symbol structures contained in memory, a processor, effectors, and receptors. Human beings have two distinctive types of memory: *short-term* (working memory) and the *long-term memory*. The instant short term type is easily accessible and provides prompt information for decision making. However, it is limited by its low storage capacity.

On the other hand, the long term memory has an unlimited storage capacity, but limited by its slow fixation time and long access time when compared to the working memory. With the acknowledgement of the limitation of the short term memory and the limited amount of information an individual can focus on at a particular time, successful problem solving is a matter of adaptation of these limitations. Miller (1956) has famously specified that *seven* pieces of information plus or minus two can be retained in a person's short term memory. However, the ability to *chunk* (organise) information into special patterns could increase the storage capacity. This can create differences between experts and novices, as experts can easily chunk and organise information in their mind in special familiar patterns that can be retrieved from their memory.

In contrast to behaviourism theory, information processing theory focusses on the process rather than the product of learning. Definitions of clinical reasoning which follow this particular theory sees the reasoning process as an internal mental process taking part in the clinician's mind when they deal with clinical cases. However, this theory may fall short in explaining the learning process taking place in novices. Furthermore, it pays less attention to the environment in which the process of clinical reasoning is taking place. The desire to assess clinical reasoning is putting more focus on the reasoning processes involved. The

Clinical Reasoning Inventory, (will be discussed later in *'How can clinical reasoning be assessed?'* section) on page 103, is an example of the assessment tools following this theory (Durning et al., 2013).

When teaching clinical reasoning to students, it is suggested to provide incremental well-organised pieces of information to the students, and modelling these pieces of information in order to improve clinical reasoning. Information processing theorists pay less attention to factors like environment and interaction between the patient and the physician in the learning process. For that reason, teaching is not necessarily taking place in clinical settings, and lectures are suggested to transfer the organised pieces of information from experts to students.

In general, both behaviourist and information processing theorist views reflect the concepts of a positivist epistemology. Their main goal is to transfer information to learner in an efficient and effective way, which includes teaching of well-organised and agreed-upon pieces of information and the removal of any irrelevant complexities such as contextual elements of the learning in order to facilitate learning (*ibid*).

2.1.3.3 Situativity theory

Situativity theory argues that knowledge, thinking and learning are situated in experience and are greatly dependent on contextual elements that cannot be separated from each other. This theory includes two main frameworks: situated cognition and ecological psychology.

Situated cognition views clinical reasoning or other cognitive processes as being located in experience. In order to understand reasoning, we need to study the characteristics of experience and situations associated with it. *Ecological psychology* argues that reasoning is the result of an interaction of a person with an information-rich environment with a goal to be reached in his/her mind.

Situativity theory focuses on the environmental characteristics of the practice settings and the interaction between the physicians, patients and other staff of the team. In this case environmental variations and interaction are seen as variables (true variance) rather than sources of noise or error, as opposed to the previously discussed theories. In this view it is argued that clinical decision making has been affected by the interaction of many factors including the environment and the participants. Although this theory takes into account the interactions between physicians, patients and settings, it does not clearly describe what drives these interactions. This deficiency can be overcome with the help of the other theories of learning, described above.

Situativity theorists view clinical reasoning as a non-linear process. Being a non-linear process, clinical reasoning cannot be measured or compared by using statistical measure to fully capture the variance in this context. In this theory, linearity may occur only in straightforward case presentations, typical disease and/or inauthentic laboratory settings. In addition, assessment should be conducted in the same environment that the task is being conducted in. It should also include the views of all participants in the encounter and setting (Durning and Artino, 2001, Durning et al., 2013).

2.1.3.4 Psychometric theory

Psychometrics is used as a method to quantitatively analyse the results of clinical reasoning assessment. Although psychometric theory is not considered as a learning theory in medical education it actually shapes and affects our understanding of clinical reasoning and other topics. It views clinical reasoning as a construct for assessment that should be both valid and reliable. If the construct cannot be measured in a reliable and valid way then it cannot be assessed. This theory shares a view with behaviourism since only observable constructs that can be measured reliably are considered to exist (Durning et al., 2013). Figure 2:3 presents a diagram illustrating the main epistemological views and the different theories stemming from each epistemology.

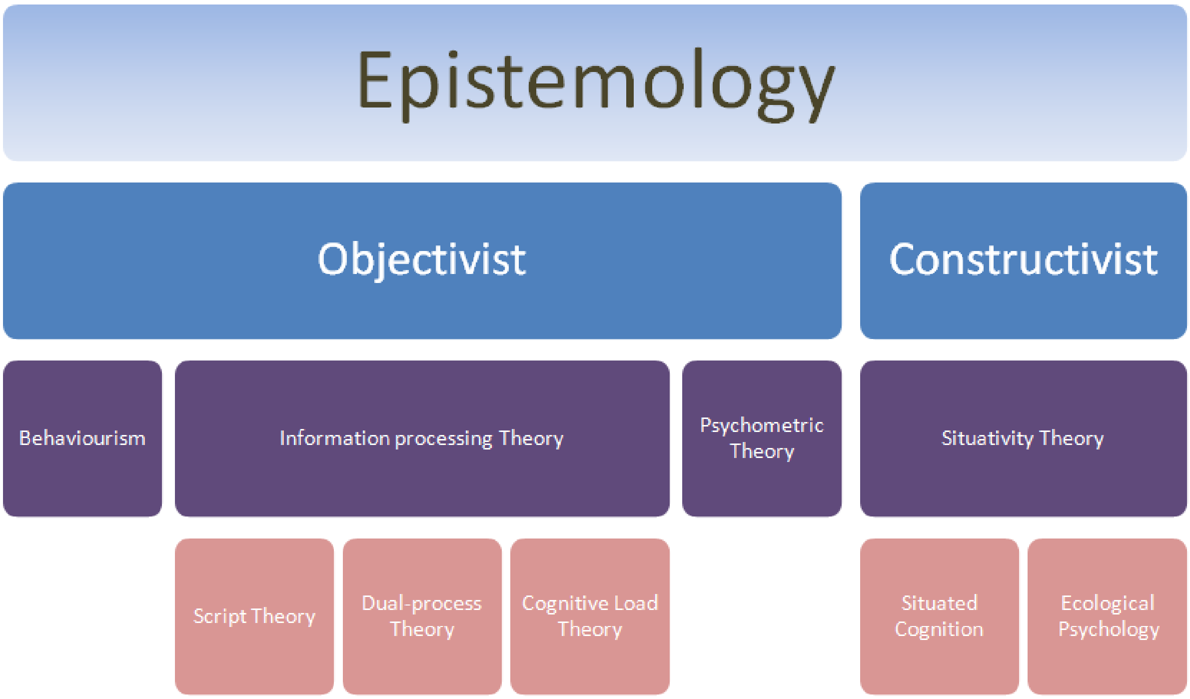

Figure 2:3: Epistemologies and related theories that shape and affect our understanding of clinical reasoning.

Table 2:1: The main differences between behaviourism, information processing and situativity theories. These differences have affected the perception of the meaning of clinical reasoning, learning process (and subsequently the teaching strategies suggested) and the assessment of it.

	Behaviourism	Information Processing Theory	Situativity Theory
Interpretation of Clinical Reasoning	Incorporates what can only be seen directly in the clinical encounter. Clinician's emotional state and thinking process are neglected.	Great value is given to the internal mental process taking place during reasoning in clinical situations. Less attention is given to the environment and other factors affecting clinical reasoning, and the interaction between them.	Clinical reasoning is likely nonlinear. Interactions between factors related to the clinician, environment, patients and other team members are considered as part of the reasoning process.
Teaching and Learning	Learning takes place through behavioural modification.	By giving the learners organised pieces of information (or modifying the existent individual pieces of information), separated from clinical settings. Complexity can then be added by including clinical settings	Authentic instructions about environment, patients and situation related factors should be involved in teaching.
Assessment	Focuses on measuring the outcome (observable actions) rather than the process of clinical reasoning.	Mainly directed towards knowledge construction and organisation.	Should be carried out within the clinical context. Many factors and their interactions are considered as true variance.

The above reviewed theories of learning (in this case clinical reasoning) can improve our understanding of the process of clinical reasoning. However, none of these theories can provide a single best answer to what clinical reasoning is. Instead, one can describe the process by combining elements of these theories.

2.1.4 The characteristics of clinical reasoning

Clinical reasoning has been presented by Orasanu and Connolly since 1993 as passing the following characteristics:

- Presence of incomplete dynamic information together with the interacting goals to be achieved, make the problem to be solved ill-structured.
- It is possible for the environment and other factors to change during the process.
- The interacting goals and priorities are prone to compete and shift during the decision-making process.

- The process occurs in the form of action-feedback loops, in which individual involved in decision-making process reacts with the results of his action and uses it to take further actions.
- Other elements may make the decision even harder such as time pressure and the individual stress.
- Decision-making process involves multiple factors acting together with different roles.
- The whole process is also affected by organisational goals, ethics and norms.

Higgs and Jones (2008a) have developed these characteristics in 2006 to deal with the complexity of clinical reasoning, as follows:

- The process of clinical reasoning is complex in its nature as it occurs invisibly in an automatic way which is not easily accessed by a researcher.
- This process is associated with visible behaviour such as recording patients' history, discussing case presentation and teaching novices.
- The interactive relationship of clinical reasoning and practice knowledge is developmental, in which they complement each other, support the meaning of each other in the achievement of practice and serve as a source of generation and development of each other.
- Clinical reasoning can be implemented as a single practitioner process or as a collaborative group process.
- Clinical reasoning can be explained as a cognitive or collaborative process; both are associated with growing imperative, explaining the need for evidence-based practice and public accountability to further understand the process.
- Language and interactive behaviour are essentials to understand and acquire clinical reasoning and practice knowledge.
- Contextual impact and the chosen or required model of clinical reasoning are both increasingly applied in recent research of clinical reasoning.
- Multiple capabilities are needed for good reasoning ability such as cognition, metacognition, emotional and social effectiveness together with the reflexive ability.
- For quality assurance clinical reasoning should be a reflexive process involving critical self-reflection to facilitate the development of reasoning ability, knowledge and communication of reasoning.

2.1.5 The nature of clinical reasoning in dentistry

Many studies have indicated that dentists are usually inconsistent in their decision-making (Kay et al., 1992, Doméjean-Orliaguet et al., 2009, Lang-Hua et al., 2014, Zafersoy-Akarslan et al., 2009, Maupome and Sheiham, 2000, Elderton and Nuttall, 1983, Bader and Shugars, 1997, Bader and Shugars, 1992). It is not uncommon to find inconsistency among different dentists in their approach to diagnosis and treatment. Based on my own personal experience during undergraduate study in a Bachelor of Dental Surgery (BDS) program, inconsistency among the clinical supervisors was very obvious when they assessed students' work. This varied approach to diagnosis and decision making could partly be a result of the insensitive and non-specific diagnostic tests used in dental practice *e.g.* vitality test: which cannot precisely denote the tooth vitality. Even the intra-oral x-ray can be interpreted differently by different dentists as stated by Balto and Al-Madi (2004).

Furthermore, the issue of inconsistency could also be a result of the difficulty of assessing the risks and the complex nature of expecting the outcomes of specific treatment options (Kay and Nuttall, 1995b). The inconsistency among dental clinical teachers may lead to varied and inconsistent feedback received by dental students during clinical education. This in turn was reported as one of the well-known sources of stress among dental students when they are repeatedly faced by inconsistent feedback received from their clinical tutors (Murphy et al., 2009). High levels of stress can consequently have a negative effect on learning and impair cognition (Jensen, 2005).

Moreover, the inconsistency in making therapeutic decision was also reported in final year dental students (Bervian et al., 2009). As a result, it is expected to have repeated calls for improving the decision support systems and practice guidelines used in dentistry (Khatami et al., 2008b). In response, Kay *et al* (2001) have developed a computer aided learning package to help dentists to make reliable and consistent decisions. However, these packages were still unable to combat the individual variations among dentists and had no effect on dentists' treatment decision-making behaviour. They suggested that research should be conducted to study the psychology of decision making in dentistry focussing on the factors affecting dentists' choice of treatment. It has been suggested that dental educators use evidence-based materials to help reduce these inconsistencies. Development of examination tools may also help *e.g.* three-dimensional imaging (Walter et al., 2009).

Making a clinical decision is not a straight forward process. The dentist usually has a number of choices and actions to be considered. Many factors interact and affect his/her decision. The decision can range from asking the patient certain types of questions when taking history, evaluating the patient's oral health and attitude, deciding on the investigations required, to the best treatment that could be delivered, taking into consideration all the important factors. These factors may be patient-related such as age, oral hygiene level, medical condition, attitude to dental treatment, gender and many others. The other set of factors could be related to the dentist him/herself. These could include mastering of specific practical skills, level of confidence in performing a specific procedure, educational background and others. Moreover, factors related to the condition of the problem, organisational and social attributes are also taking part in the interaction to make a clinical decision.

As described earlier, clinical reasoning is a complex multidimensional process. In order to describe the different factors playing a role in clinical decision making, we should start by describing the nature of the clinical settings in which the decision is taking place.

In the clinical settings most of the cases are surrounded by a degree of uncertainty, as no case is exactly typical in its presentation when compared to what is found in textbooks, research studies or even the past experience of the clinician. The case of uncertainty often adds pressure on the clinician when making a clinical decision rendering him/her considering many factors and choosing from many options. Dental practice is a dynamic setting and the characteristics of decision making in dynamic settings described by Orasanu and Connolly, (previously presented), can be applied (Smith et al., 2008).

Dentistry as a profession is historically related with medicine, especially surgery. Based on this relationship, dental education and practice is largely based on the same biomedical concepts of medicine. Moreover, dental education followed the same educational and regulatory way of medicine. However, during the 18th century in Europe and about a century later in North America, dentistry embraced a slightly different concept of the responsibilities of a clinical profession (Balto and Al-Madi, 2004).

Clinical reasoning is specific in the case of dentistry as it has variable specialities which reflect the different dental situations. In case of dental surgery, the surgeon might only see the patient for one or two visits during the treatment. Whereas dentists from other dental specialities *e.g.* endodontic dentistry, need to see the patient for more than one time during root canal treatment, and not to forget the lengthy orthodontic treatment during which an orthodontist is usually seeing the client on a regular bases for several months. In case of a general dentist, regular visits are always advised for routine check-up. In these cases a relationship is developing and may last for several years between dentists and their patients during the dental treatment. This relationship dominates most of dental specialities and affects the reasoning process. Another effect of this relationship is to favour an approach of dental care which is more towards problem preventing than problem solving and focussing more on health rather than on disease. In his description of the situation during dental treatment, Svenaeus (2000) stated that clinicians must not only evaluate their clients' pain and take a rational stand upon what they want to be done in relation to their biological state, but they should consider that these clients are worried persons who seek help and need understanding of their situation to help them return to their normal life.

Different bio-psychological factors are involved during dental treatment with two main extremes of patients. At one extreme are patients with acute pain, who are seeking immediate treatment from a dentist and show little interest in dental care. This type of patients appreciates the instrumental approach of a dentist with its emphasis on the technical expertise that will help them get rid of their severe pain quickly and easily. At the other extreme are patients with chronic orofacial pain *e.g.* 'burning mouth syndrome'. These patients need the dentist to listen and empathise with what they are feeling. They appreciate the approach called by Kleinman (1988) '*empathic witnessing*'. So, the dentist needs to differentiate and judge when to use an instrumental and when to use the empathetic approach (Khatami et al., 2008b). Other factors placing the dentist in stress during the decision making process include treating geriatric and other type of patients, such as mentally impaired patients, where it is difficult to obtain consent for treatment or where patients prefer a treatment which can contradict the dentist's ethics. Managing chronic disease requires deep understanding of the experience of the disease and the related psychosocial effects (Ettinger et al., 1990). Another common issue could be the cost of dental treatment, which is an important factor to decide on the treatment options.

However, it is not always easy for a dentist to alternate between instrumental and empathic approaches, as dentistry is usually seen as technically instrumental division. Traditionally, dental education focusses on the development of technical skills paying attention to details. The focus on manual dexterity during undergraduate dental education has produced dentists who appreciate this approach and feel that they are not working if they are not performing instrumentation such as surgery or fillings (Khatami et al., 2008a).

As a dentist, the most important feature I can recall from my undergraduate study, in a traditional type of curriculum, is the excessive amount of requirements all students needed to complete by the end of each year. These included tens of different types of tooth and root canal fillings and extractions. This approach to education made me and many other dentists always think of the quantity and the quality of the crafted work. This is further reinforced by the assessment approach commonly used in dental education where more focus is directed towards rating the levels of accuracy and assessing the end product of handwork. The issue is not only related to the assessment approach but also to the remuneration systems for dentists used in most of the countries in the world, who are only rewarded for performing instrumental tasks.

The domination of the instrumental approach in dental education was also expressed by the deficiency of dental literature to describe the factors affecting clinical reasoning as a skill or a process. There is considerably more focus on the technical aspect of dentistry expressed by studies stressing the choices available for different treatment options and factors affecting the choice of a specific option. However, dentists working in places such as multidisciplinary pain clinics should make radical changes to their attitudes and approaches to dental care where they have to pay more attention to patients' history and psychosocial state rather than surgical or instrumental needs (Loftus, 2006).

2.1.6 Key models of clinical reasoning

As a result of the different interpretations allocated to clinical reasoning, some researchers describe clinical reasoning as a cognitive process, while others see it as an interactive process. In other words, some researchers have described clinical reasoning focussing on the cognitive development taking place in the mind of the reasoning individual with little attention being made to the external factors affecting it. In contrast, factors such as the context and other individuals *e.g.* the patient have been the focus of research by other researchers and affect their explanation of the clinical reasoning phenomenon.

Different models and frameworks have emerged as a result of researching the phenomenon of clinical reasoning in the medical literature. However, these models were mainly based on studying this phenomenon in experts, with little attention given to novices' reasoning. In order to understand the current state of clinical reasoning research, the suggested types and models of clinical reasoning should be investigated (Norman, 2005). Over the past 30 years, there has been a considerable debate in the literature regarding the best model to describe the reasoning process of expert clinicians (Eva, 2005).

This section presents an overview of the common models suggested in the literature. These models can be allocated into two main groups. The first group is concerned with the cognitive process taking place during reasoning, while the other group reflects the view of the researchers who describe reasoning as an interactive process (Higgs and Jones, 2008a).

2.1.6.1 Clinical reasoning as a cognitive process

Researchers in this view describe clinical reasoning by focussing on the cognitive process taking place in the mind of the reasoning individual. Five key models have been suggested to describe cognition in clinical reasoning, as follows:

2.1.6.1.1 Hypothetico-deductive reasoning

In the literature, some researchers described it using other terms such as: procedural reasoning, diagnostic reasoning, induction-related and probabilistic reasoning. It was described in turn by Barrows *et al*; Elstein *et al* and Feltovich *et al* (Barrows and Feltovich, 1987, Barrows et al., 1978, Elstein et al., 1978, Feltovich and Barrows, 1984).

This model of clinical reasoning has described the process in steps. Clinical data and knowledge are used to generate hypotheses. Following the identification of the key features in the case, the clinician generates possible differential diagnoses. Some key features are supportive (positive predictors) and some are not (negative predictors) which guide the clinician to either support or refute a specific differential diagnosis. By repeating these steps several times, the clinician excludes some hypotheses and maintains only the working diagnosis. He/she then formulates and refines it to reach the correct diagnosis.

However, it is suggested that this model is used by novices and less experienced practitioners, and only sometimes by experts in cases of uncertainty and difficulty associated with unusual clinical cases. With increased experience, clinicians tend to rely more on pattern recognition rather than hypothetico-deductive reasoning.

This model has been further divided into inductive and deductive reasoning and a combination of the two processes. *Inductive* (forward) *reasoning* is a process that involves working through the clinical presentation of a specific case and generation of possible hypotheses to be tested in order to reach a satisfactory diagnosis.

Deductive (backward) *reasoning,* on the other hand, includes initial generalisation and formulation of a list of possible hypotheses. Repeated testing of these hypotheses leads to a conclusion and decision on the possible differential (or definitive) diagnosis.

2.1.6.1.2 Pattern recognition

This is mainly a characteristic of experts' clinical reasoning in non-problematic situations; (will be further described in '*The development of clinical reasoning'* section) on page 54. Dentists and dental students mainly use this strategy of clinical reasoning to diagnose frequent dental problems, (please refer to '*Chapter 5'* for more details).

Pattern recognition is a fast process by which a clinician can match a specific case presentation to his/her highly structured knowledge base. As his/her experience is developing, an expert formulates scripts in his/her mind for a wide range of clinical problems associated with the characterising signs and symptoms. Encountering similar cases promptly activates the required scripts to help make diagnoses (Norman and Eva, 2003, Higgs and Jones, 2008b).

In dentistry, it is suggested that the presence of some negative features in the tooth *e.g.* broken margins and old ugly filling can induce the process of pattern recognition (Maupome, 1998, Maupome, 2000, Bader and Shugars, 1997). Dental students commonly use pattern recognition to diagnose caries and other common dental conditions, rather than following the hypothetico-deductive process (Khatami et al., 2011).

However, caries scripts are different to illness scripts described in medicine. Caries scripts usually end with the decision of the need for intervention rather than a probable diagnosis. Moreover, these scripts are highly visual and less frequently tactile. Visual signs are more important than the symptoms explained by the patient (Bader and Shugars, 1997).

2.1.6.1.3 Knowledge reasoning integration

As described by Higgs and Jones (2008a) this model of clinical reasoning was suggested following the proposal of Boshuizen and Schmidt in 1992, which described a stage theory emphasising the concurrent development of knowledge acquisition and clinical reasoning expertise, (this will be further described later in this chapter on page 60).

2.1.6.1.4 Intuitive reasoning

Intuitive knowledge is associated with past experience of specific clinical cases (scripts). This can be used unconsciously during inductive reasoning. Experience and intuitive knowledge together allow an individual to develop advanced reasoning strategies or heuristics, including pattern matching and listing of items related to the working plan (Higgs and Jones, 2008a).

2.1.6.2 Clinical reasoning as an interactive process

Other models of clinical reasoning interpret it as a multifactorial interactive procedure involving individuals, associations, communities *etc*. in addition to the reasoning clinicians. This interpretation includes the following models:

2.1.6.2.1 Multidisciplinary reasoning

It is also known as inter-professional reasoning or team decision making. It is described by Loftus (2006) as a shared decision achieved by a group or a team working together to make clinical decisions for the patient *e.g.* case conferences and multidisciplinary clinics.

2.1.6.2.2 Conditional reasoning

This model is also known as predictive or projected reasoning. In this case the patient has developed certain disease or condition, or following injuries, and the clinician predicts and estimates certain outcomes and the patient's possible response to treatment. This helps the patient to reconstruct his/her life accordingly. This model was described by Fleming; Hagedorn and Edwards *et al* (Higgs and Jones, 2008a). It is most prominent in physiotherapy.

Khatami (2010) has identified this strategy to clinical reasoning in dental students. In this approach students consider and analyse all factors contributing to the problem. These include biological, psychological, and socioeconomic factors which contribute to the initiation and progression of the oral problem. Students usually referred to this strategy in analysing the sources of the problem, expecting the other consequent problems the patient may encounter, and the prognosis and outcomes of their intervention.

2.1.6.2.3 Narrative reasoning

In some cases, clinicians use stories of past or current patients to help in understanding the clinical condition of the current patient. This also helps the patient to make sense of the illness experience (Higgs and Jones, 2008a).

2.1.6.2.4 Interactive reasoning

As described by Higgs and Jones, this reasoning strategy occurs between therapist and patients in order to understand the patient's perspectives (*ibid*).

2.1.6.2.5 Collaborative reasoning

The clinician and the patient both share the decision making process. This type of reasoning actively involves the patient in making a decision especially if multiple options are available *e.g.* the choice of the restorative material to do a tooth filling. It can be also described as mutual reasoning.

According to Khatami (2011 & 2010), dental students usually discuss with the patient the treatment options available and the expected outcomes. This is done to facilitate choosing a desirable and feasible option, to share the responsibilities and to educate the patient to reach an informed decision. Furthermore, consulting with the instructors is necessary in some cases when the student is in doubt about the treatment options or where conflicts arise with the patient.

2.1.6.2.6 Ethical reasoning

This type of reasoning is frequently used in medical practice. Practitioners usually follow certain guidelines to deal with moral, political and economic dilemmas. Khatami (2010) has identified this reasoning approach in dental students when they encountered ethical conditions in some vignettes involved in her study of clinical reasoning. These students mentioned ethical guidelines, including the patient's right to know the advantages and disadvantages of certain treatment, when they discussed the presented case. Khatami also mentioned pragmatic reasoning as "*the challenge of providing the best care possible for patients who could not afford the treatment recommended*".

2.1.6.2.7 Teaching as reasoning

Practitioners use this type of reasoning purposely to encourage change in the patient's understanding, feelings and behaviour through the use of advice and instruction (Higgs and Jones, 2008a).

2.1.6.3 System 1 Vs system 2

Different models of clinical reasoning can also be allocated to another classification following the dual-process model of thinking. As described earlier, dual processing is a theory of thinking extensively explained in psychology, which consists of system 1 and 2. Researchers have applied this model to clinical reasoning (Eva, 2005). Table 2:2 summarises the main differences between the two systems.

Table 2:2: The main differences between the two systems of the dual process theory

System 1	System 2
Intuitive system	Specific to reasoning
It is tributary to emotion	Consists of conscious attitudes
Innate and also found in animals	Specific to human species
Quick thinking	Slow thinking
Influenced by emotions and experiences	based on facts and logic.
Based on perceptions of rules	Based on compliance with rules pertaining to logic
unconscious processing	conscious processing
Frequently used when making decisions	Less frequently used, uses data derived from system1
Based on associative memory	focuses on reasoning, and subject to deductive reasoning.
implicit process	explicit
Based on formed habits and very difficult to change or manipulate	More volatile, being subject to conscious judgments and attitudes.

System 1 is characterised by its quick nature. This non-analytical process allows experts to rapidly make a diagnostic decision through unconscious matching of the presented case features to similar previously encountered cases. This process is highly contextual and domain-specific (Evans, 2008).

In the medical education literature, *pattern recognition* represents the basis for the intuitive, system 1, reasoning. During this process the clinician unconsciously perceives cues from the context and the environment. These cues activate patterns stored in the long-term memory regarding a similar situation. The association between the current and past experience allows the clinician to generate hypotheses in a fast and effortless process. Pattern recognition has been suggested as the best acceptable model to explain decision-making in experts (Ericsson, 2004). However, it has also been found that it is widely used by clinicians regardless of their level of expertise (Khatami, 2010, Neufeld et al., 1981, Norman et al., 2007, Elstein et al., 1978).

System 2, on the other hand, requires some effort and is described as the analytical way of reasoning. This analytic model of clinical reasoning has been traditionally the focus of medical educational research (Eva, 2005). Experts sometimes go through this model of reasoning in difficult conditions.

Hypothetico-deductive reasoning is a representation of system 2 component of dual-process theory. By this process clinicians are involved in careful analysis of the data and repeated testing of hypotheses in order to reach acceptable diagnoses. This process has been gaining momentum as a common model to explain the reasoning process of experts and novices in medical education literature (Elstein and Schwarz, 2002).

2.1.6.3.1 Bayesian reasoning

Other models of clinical reasoning also represent the analytical process such as forward, backward reasoning and *Bayesian (probabilistic) reasoning* models. The latter can be generally described as the process in which the clinician uses mathematical formulae to calculate a probability of a certain diagnosis based on general information about the prevalence of the condition, results of the patient's test, and the sensitivity and specificity of the test performed. This model is specifically concerned with how clinicians choose between diagnoses, rather than the process of clinical reasoning.

This framework is concerned with calculating the likelihood ratio, the ratio of the probabilities of observing a specific finding in patients with or without the condition of interest. The following basic formula describes the concept of Bayesian theorem:

$$pre - test\ odds\ \times likelihood\ ratio = post - test\ odds$$

A clinician first suggests and estimates the likelihood of certain condition. This step involves working through the pre-test probability. This estimation is dependent on the prevalence of the condition in the patient's demographic group, clinical examination and results obtained from a previous test and the information gathered from the patient's history. After estimating the pre-test probability, the clinician conducts some confirming tests (Gowda and Lamster, 2011). Some variables play a role in this calculation such as the known prevalence of a disease. If the prevalence is not known, in this case the clinician's belief about the probability of the disease takes place. It also depends on the assessment by the clinician about the strength of evidence that support certain probability. For that reason, having more than one possible source of error, Bayesian framework has been criticised (Young et al., 2011, Evans et al., 2000). Despite its weakness, this framework can help clinicians and direct them towards a good method of thinking when there are a number of competing hypotheses. Moreover, it helps educators and researchers to identify sources of error in the diagnostic process (Schwartz and Elstein, 2008).

Khatami (2010) has found that the use of Bayesian framework is uncommon in dentistry, based on the fact that none of the participating dental students in her study used the Bayesian approach of numerically quantifying the probability or utility value of options. Students used the interpretive approach of combining their knowledge and experience to tackle the problem and select the appropriate options with acceptable outcomes. It has been also suggested that clinicians do not usually use carefully constructed logical pathways such as Bayesian model or decision tree to make diagnoses. They are rather more likely to draw on their past experience with similar conditions (Gowda and Lamster, 2011).

Despite the great consensus in the literature that the vast majority of diagnostic errors are cognitive in nature and usually associated with system 1 and caused by the application of cognitive bias(s), Norman and Eva found that there is very little evidence to support the association of diagnostic errors to system 1. Furthermore, it was found that errors usually happen when experts are systematic and use the analytical approach to reasoning (Norman and Eva, 2010, Sebastian, 2014, Kahan, 2012).

In addition, studies have shown that the use of these systems is not mutually exclusive *i.e.* experts as well as novices usually use both analytical and non-analytical reasoning when they deal with clinical cases (Eva, 2005, Ark et al., 2006, Kulatunga-Moruzi et al., 2001). Moreover, when a clinician (whether expert or novice) was instructed to purely use only one of these processes, this usually resulted in hindrance to the clinical reasoning process and reduction in diagnostic performance compared to the combined use of both methods (Ark et al., 2006). The combined use of both strategies can be explained by the initial use of intuitive reasoning to generate hypotheses followed by analytical testing and confirmation of the generated hypotheses. Neufeld *et al* (Neufeld et al., 1981) further stressed the importance of the use of non-analytical reasoning early in the process of diagnosis. It has been found that considering a correct hypothesis within the first five minutes of the process resulted in a very high chance, up to 95%, of getting the right diagnosis. Their finding supports the importance of intuitive reasoning.

2.1.7 What actually happens in clinical settings?

The nature of clinical reasoning for dentists differs from that of a general medical practitioner. This is similarly true for other health professions, yet it is not always clear how this process is different among different professions. This fact reflects our limited understanding of the multiple factors used by clinicians to negotiate and resolve a clinical problem. What is clear about clinical reasoning is that it is considered as a core competency for all healthcare professions (Khatami et al., 2008a).

Although there is lack of consensus about the actual process of clinical reasoning we will try to explain the process involved in clinical reasoning depending on individual experience as a dentist and in the light of Bowen's illustration regarding this process (Bowen, 2006).

The first step when a patient comes to a dental office would be to listen to his/her complaints and trying to get more information through the process of history taking. *Gathering of patient's* *information* is a skill of paramount importance during this step. During this phase a dentist should be able to differentiate between important information and the information that is of less importance to the presented case. It is the responsibility of the dentist to search for specific information from the patient's history, extra-oral and intra-oral examinations, radiographic images, occlusal analysis…*etc*. that can help him/her to perfectly work through the case in hand.

After gathering the patient's information, the dentist proceeds to the next step in which he/she represents the problem of that patient in short sentences to be written in the patient's record. *Problem representation* is another skill by which the dentist can accurately describe the problem *e.g.* acute bilateral pain related to the lower left molars. The next step is the *generation of hypotheses*, which may depend on the information stored in the dentist's mind. Experience guides the way by which hypotheses are generated. Hypotheses could be generated by using illness scripts or recalling of information stored in memory. Hypothesis generation depends on personal experience and varies among different dentists; this will be further described in the following section. During this phase, the dentist works to compare and contrast between differential diagnoses and may need to collect more information about the case depending on the difficulty of the case and the experience of the dentist.

Finally, he/she tries to rule out some possibilities, to reach the *correct diagnosis*, or it might happen directly that he/she reached the proper diagnosis. However, in some cases, which might be difficult or unusual, reaching a definite diagnosis might be not a straight forward process. In this case the dentist may consult a colleague or expert. After diagnosing the problem of the patient, the dentist steps to the *treatment planning* during which he/she will formulate a plan divided into specific well-known phases in dentistry. The actual treatment will then be carried out. Providing treatment can also be a complicated process. If different options are available for the patient, the dentist is again involved in a decision-making process. Many factors play a role in making therapeutic decisions. These include time constraints, competence of the dentist in performing a specific treatment procedure, condition of the patients, expected prognosis, the patient's preference, and many others.

2.2 The development of clinical reasoning: how is it learned?

In light of the learning theories and frameworks and models of clinical reasoning mentioned earlier, this section discusses possible explanations suggested to describe the stages of clinical reasoning development. Understanding the process of clinical reasoning development could help to formulate recommendations and strategies to enhance the learning of this critical skill in dental students.

The main role of dental education is to provide the community with well educated, safely performing, critically thinking, independently working, problem solving, highly trained and technically skilful dentists (Global Congress on Dental Education, 2015). Providing students with the required knowledge and practical training together with developing other skills are all important for dental schools in order to achieve their goals.

2.2.1 The role of knowledge

Three areas of knowledge have been defined by cognitive psychologists. These are declarative knowledge, procedural knowledge and a grey area between these two zones, in which skills of critical thinking and decision-making are located, (see Figure 2:4) on page 58.

Declarative knowledge is composed of two memory components which are explicit memory and generalizable rules. In *explicit* memory, also known as dial-up, knowledge is always ready to be retrieved by an individual when he/she calls for it. It can also be referred to as instant memory. This type includes factual information such as names and places. It also includes past memories of an individual with their associated emotions. For this explicit knowledge seven elements have been determined to facilitate effective learning in an academic setting (Druckman et al., 1991, Norman and Schmidt, 1992, Hendricson et al., 2006), as follows:

1. Communication of learning objectives for each class session.
2. Organisation of the subject matter in a manner that makes sense to the learner
3. Frequent in-class activity such as writing notes, analysing problems or answering questions
4. Use of mnemonics to aid memorisation of factual information
5. Frequent in-class quizzing with immediate feedback on response correctness
6. Total amount of 'time on task' including in-class activities and personal study time
7. Summary of key points to remember 'take-home messages' at the end of each lesson.

Generalizable rules, also known as *implicit* memory, guide an individual's behaviour in an automatic, subconscious way (Bransford, 2000, Hendricson et al., 2006). This type of memory constitutes the second component of declarative knowledge. It is also known as pop-up memory because it automatically pops-up without active retrieval when facing cueing stimuli. This type of memory is formulated by our past experience and guides our behaviour. It includes most of the individually unique mental skills that constitute expertise such as pattern recognition, which is shaped by frequently encountering the same stimuli; coping responses (modulated by previous successful actions when certain stimuli are faced); and the anticipatory guidance (which includes alertness for signals that indicate a coming event, alertness for deviation from established patterns, and the ability to anticipate future actions) (Hendricson et al., 2006).

There are five strategies which are important for the development of implicit memory, as follows:

1. Simulation of frequently encountered problems as well as the rare clinical cases in which students are facilitated to make decisions.
2. Prospective type of simulation. In this case students are guided to analyse scenarios to predict likely problems and develop coping strategies.
3. Retrospective critique of case scenarios which allows students to review their actions
4. Marking performance against best practice benchmarks in a process of self-assessment.
5. Reflection, written or verbal, on the meaning of experience focussing on possible ways of avoiding errors.

Source: (Hendricson et al., 2006)

The second area of knowledge is known as **procedural knowledge**. This type of knowledge is associated with how to do things and consists of discrete (isolated action) performance and continuous action types of performance. *Discrete procedure* is a well-defined sequential action with definite start and finish points. It also has predictable outcomes which can be easily measured. It does not usually need extensive effort and load on the memory, as it has well-known steps to be performed. Dental students for example know how to develop an x-ray film by following a sequential procedure.

In contrast, *continuous procedures* involve series of action which need to be coordinated with continuous monitoring of the environment, such as driving a car. Success of continuous actions critically depends on the function of the cognitive centre of the brain and the metacognition procedure which allows the individual to assess his/her performance and how things are going with regards to the environment and modify actions accordingly (Hendricson et al., 2006). In dentistry, managing to use the handpiece is an example of this type of procedure. Dentists are used to deal with the handpiece, however, the precise position and pressure used depend on the situation and the condition. The dentist should be alert to the sudden tongue movement and use his/her metacognition to review the position of the handpiece. Moreover, he/she is required to adapt the magnitude of the applied pressure according to the depth of the bur in the different tooth layers. There are six suggested strategies to help students to develop procedural skills, as follows:

1. Practice describing, visualising, or drawing the desired end-product
2. Comparing the desired outcomes to the unacceptable examples of outcomes.
3. Observation of the procedure conducted by an expert with elaborated explanation
4. Frequent practice of the procedure with a supervisor, whose job is guiding and correcting the action, focussing on helpful tips.
5. Prompt feedback if errors are encountered.
6. Self–assessment against best practice standards.

Source: (Hendricson et al., 2006)

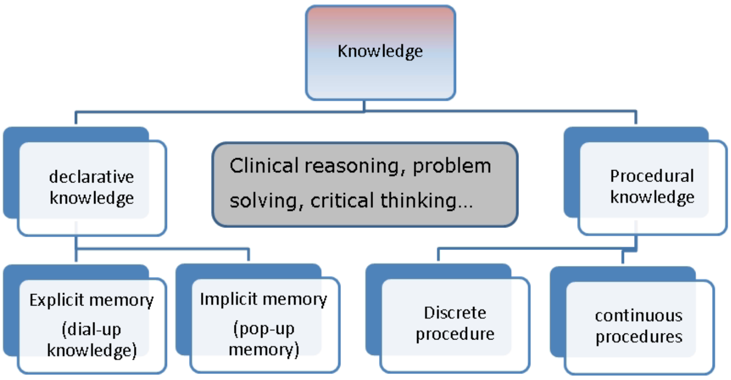

Figure 2:4: Different types of knowledge affecting the development of clinical reasoning

By using advanced brain imaging technologies, neurophysiologists were able to study brain functions of experts and novices during problem solving tasks. It has been found that expert practitioners have the ability to integrate neural networks that facilitate quick retrieval of chains of information regarding the problem and the situation. Novices on the other hand, despite having encyclopaedic information, may struggle to assemble isolated bits of information. More recently, experts are argued to have greater neural activity and processing efficiency in certain regions of their brains *e.g.* the prefrontal cortex during non-analytical reasoning (Durning et al., 2015). The following section will discuss clinical expertise and its role in clinical reasoning development.

2.2.1.1 Biomedical and clinical knowledge

Basic science or biomedical knowledge involves subjects like anatomy, biochemistry and physiology. This type of knowledge is seen as an important factor affecting the development of clinical reasoning by providing sound basis for developing clinical reasoning.

Clinical knowledge is the knowledge concerned with disease entities and associated findings. During the process of clinical reasoning, both types of knowledge are important (Kaufman et al., 2008).

The relationship between biomedical and clinical knowledge has been studied in the medical education literature. Two main hypotheses are presented in this section (Schauber et al., 2013). The first one is what was suggested by Kaufman *et al* and Patel *et al* as these two types of knowledge are stored separately in the mind of medical practitioners. Although they addressed the importance of biomedical science knowledge, they suggested that expert clinicians do not actually rely on it when dealing with clinical cases. Experts mainly depend on pattern recognition and their association to common clinical presentations. According to this hypothesis, experts use biomedical knowledge only if pattern recognition is not possible such as in the case of unusual or difficult clinical cases (Kaufman et al., 2008, Patel et al., 1989, Woods et al., 2007).

The second approach, however, sees medical expertise as an incrementally developing process in which the knowledge base is changing regularly in a process known as knowledge encapsulation. This model was described by Boshuizen, Schmidt (1990), Norman and Rikers *et al* (2004 & 2005).

Although both approaches explain the relationship between the biomedical and clinical knowledge differently, both have stressed the importance of biomedical knowledge in gaining expertise in clinical reasoning.

A recent study has suggested that there is a negative relationship between biomedical knowledge and clinical knowledge on medical students on a traditional curriculum. This might also suggest the inappropriateness of the separation of the two types of knowledge in the traditional curriculum (Schauber et al., 2013).

2.2.2 The role of experience in the development of clinical reasoning

"*Clinical reasoning is the vehicle for experiential learning from practice*" (Christensen et al., 2008). Despite the importance of knowledge in clinical problem solving, applying this knowledge in practical settings is even more important. The role of experiential learning (learning from clinical experience) has received great attention of authors who believe that clinical reasoning capability develops through experiential learning from clinical experience (Mattingly, 1991). Since experience is widely considered as a common determining factor for clinical reasoning, as argued in the literature, this section discusses the development of experience and its relationship to clinical reasoning in medicine and dentistry.

It is important to understand expertise because it can provide useful clues and adds to the understanding of the nature of thinking and problem solving behaviour. Research in problem-solving and clinical reasoning began by mainly studying the differences between experts and novices in their ways of thinking. One of the earliest studies was conducted by De Groot in 1965. He was keen to find how the world-class chess masters always out-play their opponents and he concluded that "*we know that increasing experience and knowledge in a specific field (chess, for instance) has the effect that things (properties, etc.) which, at earlier stages, had to be abstracted, or even inferred are apt to be immediately perceived at later stages. To a rather large extent, abstraction is replaced by perception, but we do not know much about how this works, nor where the borderline lies. As an effect of this replacement, a so-called 'given' problem situation is not really given since it is seen differently by an expert than it is perceived by an inexperienced person…"*

2.2.2.1 Common characteristics of novices' and experts' reasoning

Research has shown that there are considerable variations between novices and experts in their problem solving abilities (Patel et al., 1996, Smith et al., 2010). The definition of experts indicates that they are able to think about problems in the field of their expertise more effectively than less experienced individuals (Bransford, 2000).

Despite the considerable variations in the reasoning process characterising novices and experts, they share some common characteristics (Grant and Marsden, 1987, Neufeld et al., 1981, Bordage and Zacks, 1984). It was found that medical students used clinical reasoning methods that are similar in structure to that of doctors. Similar elements of the diagnostic process were found in both students and doctors. These elements included the timing and the number of generated hypotheses. However, only one process was found to be enhanced by the level of education: the content and specificity of diagnostic hypotheses. This important process was also the best predictor of clinical reasoning outcomes (diagnostic accuracy) (Neufeld et al., 1981).

Sharing of some similarities between experts' and novices' clinical reasoning characteristics have been also suggested in dental literature as well. In a study conducted by Maupome *et al* (1998) it has been found that dentists and students took about as long to complete their visits with the patient and same time for evaluating the patient's oral health. Moreover, both groups used the same number and range of DTPs[1] and excluded the same DTPs. Maupome *et al* concluded that students and dentists had broad

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[1] DTP (Diagnostic Thinking Processes) is a model developed by Gale and Marsden to qualitatively assess the process of clinical decision making. This model is composed of steps, identified by serial numbers, that each clinician or medical student proceeded through during their decision-making process (Gale and Marsden 1983).

similarities in their diagnostic strategies. However, some differences were found between the two groups. Dentists identified key features of the clinical case information through their more frequent used of DTP2 (diagnostic interpretation of clinical information). Students at the same time were searching for more information through DTP3 (judgement of the need for further general or clarifying enquiry) to make sense of clinical information. Another difference between the two groups was that dentists used DTP9 (routine enquiry) in the final quarter of the visit, whereas students used this earlier. This could be explained by the students being hinged on accruing information conforming to the routine enquiry plan in which they first completed the medical and dental history, whereas dentists felt more confident in addressing or revisiting this routine enquiry later in the visit. Furthermore, the use of concepts was different among the two groups. Dentists more frequently asked questions about general health status and used more concepts related to dental visit patterns, oral hygiene, and overall dental status. On the other hand, students were more concerned in using radiographic, restorative and dental caries concepts earlier on in the visit.

As described earlier, results of studies which describe the process of clinical reasoning in dentists having different levels of expertise suggested that experts commonly use forward reasoning when dealing with difficult cases, whereas students and less experienced dentists utilise backward reasoning. However, according to Khatami *et al* (2008b), the results are not absolute as experts and novices can move forward and back ward during the reasoning process and such a conclusion cannot be made. Further description of the clinical reasoning process suggests that expert dentists commonly rely on their experience when managing a dental problem, whereas students and less experienced dentists rely more on textbooks and the didactic part of their education.

Another difference in the process of clinical reasoning was suggested by Crespo *et al* (2004) who concluded that, in contrast to novices, expert dentists show more appreciation of psychosocial factors of the patients during their decision making. Additionally, expert dentists commonly favour the use of past experience of similar cases during their reasoning rather than working through (H-D) model (Ettinger et al., 1990). However, it is suggested that practitioners with different levels of expertise use combination of methods and models in their decision making process as stated by Eva and Norman (Norman, 2005, Eva, 2005).

Another difference described by Dutton (1995) was that a novice student has a limited level of flexibility in applying the rules and principles learnt in school without the considerations of the particular circumstances associated with each specific case when compared to experts. Table 2:3 summarises the main differences between experts' and novices' reasoning.

Bransford *et al* summarised the key areas in which experts are recognised, as follows:

- Experts notice features and meaningful patterns of information that are not noticed by novices.
- Experts have acquired a great deal of content knowledge that is organised in ways that reflect a deep understanding of their subject matter.
- Experts' knowledge cannot be reduced to sets of isolated facts or propositions but, instead, reflects contexts of applicability: that is, the knowledge is 'conditionalized' on a set of circumstances.
- Experts are able to flexibly retrieve important aspects of their knowledge with little attentional effort.
- Though experts know their disciplines thoroughly, this does not guarantee that they are able to teach others.
- Experts have varying levels of flexibility in their approach to new situations.

Source: (Bransford, 2000)

It has been also found that experts share common characteristics which can differentiate their problem solving skills from those of less experienced practitioners. These characteristics include:

- Experts can understand the needs of individual patients more than novices. They can also customise their decision to meet the requirements of each specific patient.
- They are more inclined to involve the patient when making treatment decisions. They tend to educate patients about their cases and make a collaborative decision.
- Experts have a high level of reflection by which they can create individual philosophy of practice and modify their behaviour to improve the outcomes
- They also know when they can deviate from the rules and use that effectively to suit the individual needs of their patients.
- Experts use more organised knowledge and they usually use pattern recognition and rapid forward reasoning strategies.
- Experts critically assess new knowledge
- Experts are more flexible and able to handle distractions in the context to provide the best care for the patient in a specific environment.
- They express high levels of confidence and spend less time thinking about possible failure of their decisions
- Clinicians often unconsciously use multiple strategies to deal with clinical problems
- They usually have the ability to anticipate the outcomes of specific problems and treatment options. The use of scripts by experts has been also described as heuristic reasoning
- Experts generate few defined hypotheses early in the clinical encounter.
- Experts have the ability to chunk or organise information into familiar patterns that are easily accessible (information processing theory)
- They have knowledge that is useful, retrievable and situation-specific (situativity theory)
- They have the ability to maintain personal composure away as emotions can adversely affect making suitable decisions
- They usually have a high level of confidence when making decisions, even in cases of uncertainty
- Research has shown that experts use heuristics (thinking strategies), past experience and formal education to efficiently use their short-term memory and rapidly access the information stored in their long term memory.
- More motivated to provide the best care for the patient.

Sources: (Miller, 1956, Evans et al., 1991, Thomas, 1992, Patel et al., 1996, Simmons, 2003, Bowen, 2006, Smith et al., 2010, Gowda and Lamster, 2011, Hong Kong Polythechnic University, 2014).

Table 2:3: Characteristics of the behaviours followed by novices and experts when they face a problem, Source: (Hendricson et al., 2006).

Novice Behavior	Expert Behavior
Rule bound; tries to implement textbook approaches	Adapts to circumstances; not locked into one particular strategy
Slow and hesitant; lacks confidence in decisions	Fast and fluid; confident about decisions; optimistic
Looks for help or even "bails out"; overwhelmed by uncertainty and ambiguity of the situation	Takes charge and provides leadership even when situation is ambiguous and outcome uncertain
Cannot access pertinent knowledge quickly	Quickly retrieves needed knowledge by largely subconscious recall of pertinent information
Slow "trial and error" efforts to solve the problem using one approach at a time; slow to recognize when strategies are not working	Settles on "best course of action" after quick review of options but willing to change course quickly if results are not satisfactory
Singular: concentrates on own needs and own discomfort in ambiguous situation; inefficient; does not manage time or resources well	Multi-task: can simultaneously study the problem and also coordinate work of others
Focus: surface features of the problem	Focus: underlying problem source
Flawed thinking:	Accurate: makes correct decisions
• Premature closure—makes decisions too fast	Avoids flawed thinking
• Anchoring—stubbornly supports poor decisions	
• Faulty synthesis—2 + 2 = 6	
• Ignores or doesn't recognize important data	

2.2.2.2 Development of the clinical reasoning expertise:

Dental undergraduate education tries to move students from the left hand side to the right hand side of the characteristics illustrated in Table 2:3. Despite extensive research conducted to understand the difference between novices and experts regarding the development of clinical reasoning, little is known about how expertise is gained. What is known is that experience is a necessary, but not a sufficient, condition for expertise (Dasari, 2006).

Research shows that the development of expertise is not a simple process. Its complexity could be explained by the fact that expertise cannot not be considered as a general ability, such as memory or intelligence. Moreover, it cannot be developed by simply acquiring and expressing some strategies consistent with those of experts. Rather, experts commonly have extensive knowledge which manipulates their receiving of information in relation to the environment and the organisation of knowledge, and consequently affects how they manage problems.

Stage theory is suggested to explain the development of expertise in medicine. This theory suggests the importance of the simultaneous development of knowledge acquisition together with clinical reasoning in the process of expertise development. Students usually acquire a large amount of biomedical science knowledge in their early stages of medical education. They then keep learning new concepts that are used to connect these pieces of knowledge. Over time, more concepts are learnt and a knowledge network is developing and refined to produce better connections. Students in this stage focus on their knowledge base, trying to evaluate and integrate information from different disciplines. Clinical reasoning in this stage is characterised by the detailed elaboration on knowledge with specific lines of reasoning. This is the reason behind the extensive seeking of more information by students in this stage. They usually search for more information and try to match them to their knowledge network. This process is time consuming. Moreover, these pieces of information are not linked to signs and symptoms characterising the disease they are dealing with. Extensive elaboration is a common feature of clinical reasoning in novices. It is also characterised by being untidy, less goal-oriented and based on generation of less plausible hypotheses and less accurate diagnoses (Boshuizen and Schmidt, 2008).

The next step can be described as *knowledge encapsulation* (Schmidt and Boshuizen, 1993), which is characterised by the ability of students to make more connections between reasoning concepts within separate knowledge network. They make direct lines of reasoning between concepts within the previously formed knowledge network. With the repeated activation of these direct lines, associated concepts are clustered together and the student can make use of the first and last concept through the new connections made, skipping the intermediate ones. Students in this stage can use some short cuts when dealing with clustered concepts. This happens at the end of their knowledge acquisition stage. This stage is also characterised by the use of some clinical terms which may provide a powerful tool for clinical reasoning.

Encapsulation of biomedical knowledge allows students to progress to the next step towards the development of clinical reasoning expertise. During this stage students are continuously integrating biomedical concepts and clinical knowledge. They mainly focus on the clinical information of the clinical cases, formulating hypotheses or diagnoses. They make use of biomedical knowledge in some cases when they deal with difficult clinical cases. However, it has been argued that activation of biomedical science knowledge is also a feature of experts' clinical reasoning. Experts use this knowledge instantly when they need it (Rikers et al., 2005).

Almost concurrently, students start to use *illness scripts*. Instead of networked organisation of knowledge, another structure of organisation is formed and students usually rely on it at this stage. As more illness scripts are formed, students move towards gaining more expertise in clinical reasoning. These scripts are shortcuts by which physicians relate the factors leading to a specific condition to the fault in the disease itself. Moreover, consequences of this fault are also available in the form of signs and symptoms. By using illness scripts, advanced students seek specific information from the patient's history, examinations and investigations in order to match them to the previously-activated illness script (s). Signs and symptoms usually support the activation of certain scripts and deactivation of (irrelevant) others. The use of illness scripts also activates the expectation of other findings. Students may also seek more information to discover other signs and symptoms of the disease. This in turn leads to formulation of differential diagnoses or even definitive ones. Illness scripts are continually formed and replace the knowledge network organisation. The more scripts formed, the more expertise gained. The use of illness scripts is a common feature of experts' reasoning; during problem solving tasks, experts activate a few illness scripts and match them to the clinical case they are dealing with (Verkoeijen et al., 2004, Norman and Eva, 2003, Groves et al., 2003b, Durning et al., 2012, Charlin et al., 2000b).

Experts' clinical reasoning involves extensive use and reliance on illness scripts. During regular clinical practice, no active clinical reasoning is involved. Instead, experts use spontaneous scripts. However, when they encounter difficult clinical cases, they revert to engage in an active process of clinical reasoning. This activation may involve the use of modified scripts or even unfold the encapsulated biomedical science knowledge to be used (Boshuizen and Schmidt, 2008).

2.3 Factors affecting the development of clinical reasoning skills and clinical decision making

Competing goals and many factors are interacting and further complicate the process of dental decision making; some are related to patient-, and practitioner- characteristics and some are related to the profession itself (Kay and Blinkhorn, 1996, White and Maupomé, 2003). When asked to list the main factors affecting their treatment choices dentists were varied in their responses. This was indicated by the findings of a study conducted by Brennan and Spencer (2002). In this study, a sample of dentists was asked to choose between alterative treatment options for a list of clinical cases. They were also asked to provide a list of factors that affected their choices of the treatment options in each case. In response, they provided varied lists of factors with different priorities. The study concluded that this variation could be responsible for the individual variations in treatment decisions common in dentists, as mentioned earlier.

This section reports on factors that could influence clinical reasoning and decision making, based on research conducted mainly in the field of medicine and to a lesser degree in dentistry due to the limited literature of this type of research in dentistry (Gowda and Lamster, 2011). As we have treated clinical reasoning and clinical decision-making synonymously earlier in this research, we now are keen to separate the two terms in this part of the research. For clarification, clinical reasoning as a skill would be treated separately from clinical decision making as a process. This separation would help to focus, in the first part, on the factors affecting clinical decision making, which is a component and the outcome of the clinical reasoning process. The second part mainly focuses on factors affecting the overall skill of clinical reasoning (especially factors related to the decision maker), although some of the factors have mutual effects on both processes.

Smith *et al* (2008) have categorised the factors affecting clinical decision making into four attributes: task attributes, including uniqueness, certainty, importance, stability, urgency, familiarity and risk; attributes regarding the nature of the decision task, which refer to the conceptualisation by a decision maker of the decision and the outcomes to be achieved; attributes of the decision makers, including knowledge base, personal frame of reference and individual practice model; and finally, attributes of the external context including the working environment. In the following sections the main factors are divided into: task attributes, patient attributes, external context (environmental) attributes and attributes related to the decision maker. Figure 2:5 below summarises these factors.

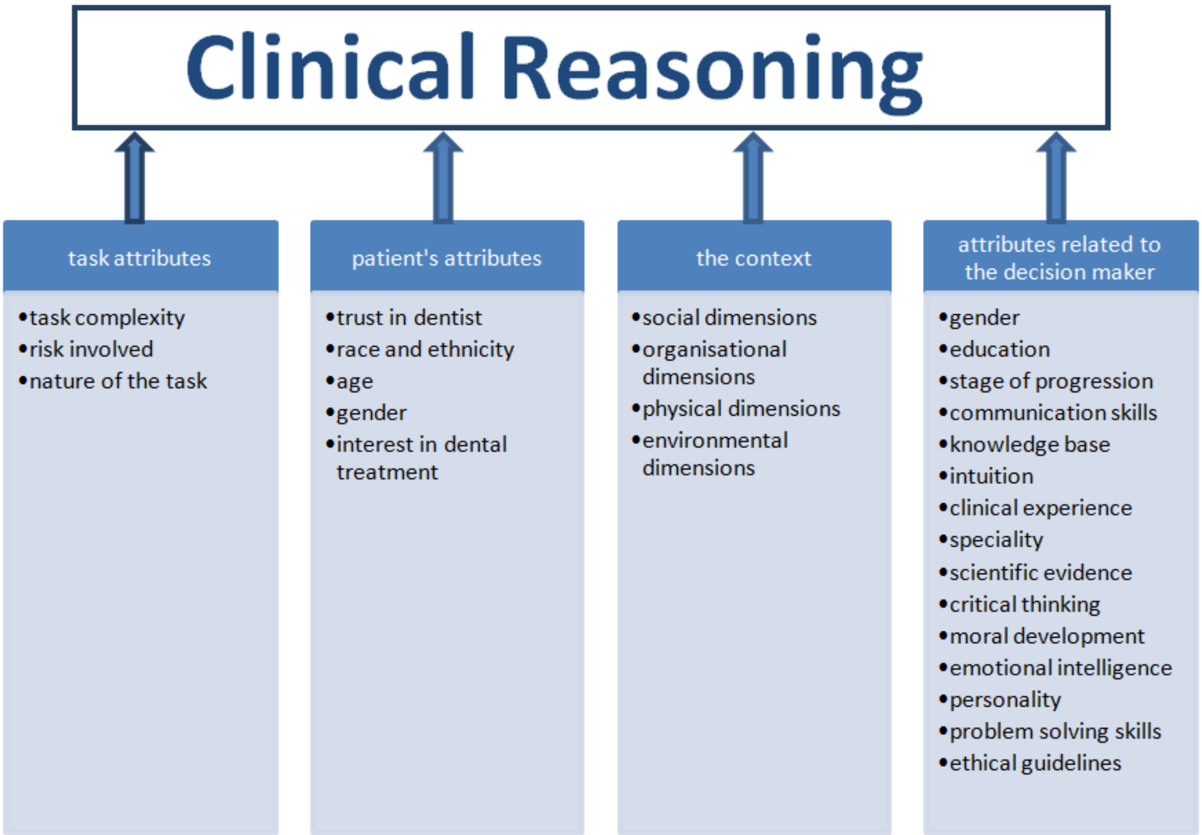

Figure 2:5: Factors affecting clinical reasoning (from: Elderton and Nuttall, 1983, Grembowski et al., 1988, Evans, Stanley et al. 1991, Kay and Nuttall 1994 & 1995a, Oates et al., 1995, Kay and Blinkhorn ,1996, Patel et al., 1996, Redford and Gift, 1997, Eva et al., 1998, Lyneham, 1999, Knutsson et al., 2001, Brennan and Spencer 2002, Chapple et al., 2003, Groves et al., 2003a, White and Maupomé, 2003, Balto and Al-Madi, 2004, Cabral, Caldas et al., 2005, Eva 2005, Windish, Price et al. 2005, Anderson, 2006, Bowen, 2006, Smith et al., 2007, Zadik and Levin 2007, Akeel, 2008, Christensen et al., 2008, Pau and Elder, 2008, Small, 2008, Smith et al., 2008, Chambers, 2009, Croskerry, 2009, Doméjean-Orliaguet et al., 2009, Stempsey, 2009, ÖZhayat et al., 2009, Broers et al., 2010, Cerullo and Cruz, 2010, Fox, 2010, Geary and Kennedy, 2010, Glick, 2010, Khatami 2010, Omar and Akeel, 2010, Smith et al., 2010, AlanI et al., 2011, Straub-Morarend et al., 2011, Wainwright et al., 2011, Youngson, 2011, Zitzmann et al., 2011, Ashoorion et al., 2012, Narby et al., 2012 , Pardamean, 2012a, Da Silva, 2013, Hong Kong Polythechnic University, 2014, Lang-Hua et al., 2014, Shafaroodi et al., 2014, Williams et al., 2014).

2.3.1 Task attributes:

2.3.1.1 Task complexity

The nature of the task can affect the decision-making process and the reasoning strategy to follow. As described earlier, clinicians usually approach clinical cases differently based on the complexity of the clinical case they are dealing with. For straight forward cases they usually follow the fast system 1 reasoning including pattern recognition and scripts. On the other hand, if the task to be solved involves unusual clinical cases or the clinical presentations were incompatible with the stored scripts, system 2 will dominate the reasoning process. However, there is always a possibility for using mixed strategies when making clinical decisions.

2.3.1.2 Degree of risk involved

Risk was defined by Smith (2008) as "*the estimation of the chance of an adverse or negative outcome occurring as a result of the decision*". In case the decision involves identifying high risk of life threatening conditions, clinicians usually carried out extensive investigations in a strategy known as 'rule out worst case scenario'. However, frequent reliance on this strategy in all cases irrespective of the level of the risk involved, may lead to over-investigation of patients and extensive use of resources, reducing the efficiency of decision making especially in emergency cases (Geary and Kennedy, 2010).

Early detection and identification of some characteristics in oral lesions by a general dentist could be critical to diagnose oral cancers in their early stages. In some cases the patient might not develop symptoms or may not even be aware of the presence of such lesions. The patient can then be referred to a specialist for more investigations. Some oral lesions have high morbidity rate such as pemphigus vulgaris, which is an autoimmune disorder. This disorder can be presented in form of ulcers in the tongue of the patient which can be easily misdiagnosed. Other conditions also cause oral ulcers such as herpetic gingivostomatitis and aphthous ulceration. Careful history taking and early biopsy are recommended to avoid the complications of the condition, which is associated with a high rate of morbidity. It is also important to make the right diagnosis as the treatment plan differs according to each condition.

In contrast, caries and periodontal diseases are common dental problems which might not be life threatening to the patient. Caries risk and the risk of developing periodontal diseases can be estimated by the dentist by investigating the current state of the disease together with the overall oral health and the other patient's characteristic such as oral hygiene and age. The level of the risk of developing dental problems can also affect the decision to intervene by the dentist (White and Maupomé, 2003). Furthermore, it has been found that technical factors *e.g.* periodontal status and caries rate affects the decision on the choice of treatment option available (Grembowski et al., 1988).

In addition to the risk of the condition, risk of the procedure to be carried out is also considered as one of the factors playing role in decision making. A dentist may avoid performing a risky procedure for patients in cases where he/she has limited experience or lacks confidence in conducting such a treatment procedure. It has been found that endodontists usually opted to perform low risk procedures depending on their subjective decisions of the benefit to intervene as reported by Kvist and Reit in 2002. Some procedures may involve high risk of failure such as inserting an implant in close proximity to the maxillary sinus. This procedure can produce serious complications to the patient such as sinus perforation. In summary, assessment of the level of risk together with avoidance of risk are considered to be factors affecting clinical decisions (Stempsey, 2009).

2.3.1.3 Nature of the task

The nature of the task has an impact on the decision-making process. Acute cases in which the patient comes in severe pain require the dentist to take prompt action to deal with this pain in the first place, rather than performing special diagnostic tests to search for possible causes. In cases of emergency such as fractured jaw, dental trauma or tooth avulsion, dentists' reasoning might be similar to that for other clinicians in emergency clinics. Emergencies can also suddenly arise during dental treatment such as diabetic coma due to anxiety of dental treatment in diabetic patients or aspiration of a tooth following extraction. Unfortunately, the dental literature is deficient in its description of decision making in case of emergency, but it has been found that nurses usually use Hypothetico-deductive reasoning utilising verbal, non-verbal and other sources of information in emergency situations (Lyneham, 1999). Moreover, in emergency medicine it has been found that clinicians use pattern recognition as well as analytical reasoning and a mixture of the two processes in case of emergency (Geary and Kennedy, 2010).

2.3.2 Patient's attributes: The role of the patient in the decision making process

Traditionally, the physician was responsible to take the best decision on behalf of patients. However, with the current shifting towards a more patient-centred approach in health care, patients are getting involved in the decision making process (Smith et al., 2008). There has been a recent shift of dental care to express greater focus on the psychosocial aspect of clinical cases (Khatami and MacEntee, 2011). Many studies have stressed the important role of patients in making a treatment decision (ÖZhayat et al., 2009, Narby et al., 2012).

Although the role of the patient in participating to make a decision is reinforced frequently especially with the research being more inclined towards a patient-centred approach, this role is suggested to be limited in dentistry. According to a published study, despite the fact that all of the participating dental patients have expressed desire to participate in treatment decision making, these patients perceived themselves as having passive roles in decision making due to their lack of dental knowledge and their high level of confidence in their dentists (Chapple et al., 2003). Recent research has suggested the use of a visualised decision board to increase patients' knowledge about their dental problem and transparency for the patients. However, this aid was suggested to have no effect on the patients' satisfaction regarding a treatment choice (Kupke et al., 2013).

Most dental clients, when they have trusted their dentists, tend to defer to their dentists rather than being actively involved in the process of decision making. However, this is not the case if the patients did not have a confidence in their dentists. These patients tended to participate more in making decisions rather than being passive (Chapple et al., 2003).

As mentioned earlier, in dental practice clients may have multiple visits and frequent check-up appointments to the dental office. It is not uncommon for a relationship to develop between them and their dentists. This relationship in turn can have an effect on the treatment decision making process. Just like other care providers, the dentist and his/her patient are both affected by multiple non-clinical factors when they interact. The interaction between them has been argued to have a great effect on the clinical decision making of the choices of treatment and is mediated by many psychosocial factors *e.g.* the personality and the examination style of the dentist (Redford and Gift, 1997).

Patient-dentist relationship was argued to be the most important determinant for an extensive restorative treatment decision making. However, multiple barriers can have a great effect on the decision made by the patient. These barriers include: fears, anxieties, the costs of dental treatment, the time spent to obtain treatment and the access to dental care (Oates et al., 1995). Cost, trust in the dentist and anxiety towards dental treatment have been reported to affect the patient's decision, which in turn affects clinical decision made by the dentist (Narby et al., 2012).

Other patient-related factors have also been reported to affect the decision-making process. A patient's race or ethnic origin for example has been suggested to have an effect on the decision of dentists. In a study conducted by Cabral *et al*, it has been found that dentists favoured a less conservative approach for black patients. These dentists preferred extraction for badly decayed teeth rather than saving them by performing root canal treatment and crowns (Cabral, Caldas et al. 2005). It has been also found that some characteristics of the patients may affect the dentists' decisions. Minimally invasive aesthetic restorations were preferred by the dentists participating in a study when the patients were healthy, young and well-insured, regular attenders with good oral hygiene. On the other hand, the gender of the patient did not affect the treatment choice by the dentists who participating in the same study (Doméjean-Orliaguet et al., 2009). Age of patient has been identified as another factor affecting the treatment decision by dentists. Tooth extraction was a common choice of treatment for older patients (Zadik and Levin 2007).

Kay and Nuttall (1995a & 1994) argued that dental treatment decision was greatly affected by the values the patient places on the outcomes of a specific treatment option. They recommended that dentists take into consideration the preferred outcomes from a specific treatment option as perceived by their patients. The interest of dental patients has also been reported to change from what it used to be in previous decades. Patients are now seeking more aesthetic options and are more concerned with the final appearance of restorative treatment. This factor could have an impact on the decision making process by the dentists (Small, 2008).

2.3.3 The context

Context has a great effect on the decision making process. There is a consensus in the literature about the importance of context in clinical reasoning. The importance of context has been empathically expressed by Croskerry (2009) in his article titled '*Context is Everything or How Could I Have Been That Stupid?*'

Different types of contextual factors may affect the decision making process. These include: social, professional, organisational, physical and environmental dimensions. The interaction between context and decision making was found to be complex and dynamic in nature. Certain contextual factors have been found to play variable roles and could not be ranked, as their priorities differed according to the circumstances at a given time (Smith et al., 2008).

Contexts of the clinical problems are different in different health care divisions. Much of research regarding the effect of context on the problem solving process has been conducted in physiotherapy, occupational therapy, and nursing (Shafaroodi et al., 2014, Smith et al., 2007, Wainwright et al., 2011). These fields have specific task characteristics. The situation is different in the case of dental practice and cannot be applied in this case. The context of the clinical problem can change the strategies of problem solving by the same clinician (Eva et al., 1998). However, experts can modify and manipulate environmental factors to provide the best patient care, please refer to the '*Common characteristics of novices' and experts' reasoning'* section on page 61 for more explanations.

It could be suggested that the reasoning process for dentists differs according to the context (the environment) they work in. The situations in primary care clinics require the dentist to provide general dental care and deal with frequently encountered dental problems. In this case clinical reasoning could be expected to follow pattern recognition. This suggestion can be supported by the findings of Khatami's study in 2010, who has argued that pattern recognition is common not only in dentists but also in dental students when they deal with the common dental problems. This study has found that dental students use caries scripts, periodontal scripts and mucosal disease scripts to diagnose and detect caries, assess the periodontal tissue condition and mucosal problems, respectively. It has also been found, as described by the participating students, that contextual factors such as the available clinical facilities could pose barriers to achieving the desired outcomes.

The results of our qualitative study, to be presented in Chapter 5, indicated that in some cases, especially when the student was uncertain about the best decision to choose, they referred to other individuals in the context including a student colleague or a specialist. This finding may suggest the importance of social factors in the clinical environment in making a decision.

Patel *et al* (1996) reported that decision making can be influenced by the hierarchy and social structure of the organisation. Similarly, Khatami (2010) has found that dental students' decisions about a treatment choice were largely affected by the authority of their clinical instructors even when the students believed that the instructors chose the wrong option for the patient.

2.3.4 Attributes related to the decision maker

As previously mentioned, dentists vary considerably in their decisions about diagnosis and management options. It has been found that in the case of caries detection, dentists usually make their diagnosis based on pattern recognition; mainly visual cues are the trigger. When it comes to the decision on the type of filling material to be used or any management procedure to be carried out, dentists usually make subjective decisions about the overall situation of the current patient. They subjectively evaluate caries susceptibility and risk for recurrent decay and adapt their decision accordingly (Doméjean-Orliaguet et al., 2009). There is limited research in dentistry regarding what dentist-specific attributes can be responsible for such varied decisions. There are repeated calls for more studies to clarify the dentists' related factors, which can affect their decisions as argued by Fox (Fox, 2010). The following fifteen attributes were suggested to play important roles in the development of clinical reasoning skills.

2.3.4.1 Gender

It is argued, in the medical and dental literature, that there is no correlation of gender difference with the level of clinical reasoning ability in undergraduate students (Ashoorion et al., 2012, Anderson, 2006, Hong Kong Polythechnic University, 2014, Shafaroodi et al., 2014, Da Silva, 2013). Furthermore, gender has been suggested to have no effect on the treatment decisions taken by male and female dentists except that female dentists preferred referring patients to specialists rather than performing complex therapeutic procedures (Zitzmann et al., 2011).

However, Groves *et al* (2003a) conducted a study to examine the gender effect on clinical reasoning ability of medical students using two different types of clinical reasoning assessment namely Clinical Reasoning Problems (CRP) and Diagnostic Thinking Inventory (DTI). The findings of their study suggested that although female gender was a positive predictor of clinical reasoning ability, this was approved only for CRP and not for DTI. Explanation was provided by the authors that this might be because female students tend to be more careful and thorough in their approach to diagnosis as they can deliberately identify all critical features from case presentation. More explanation about clinical reasoning assessment tools will be presented later in '*How can clinical reasoning be assessed'* section on page 103.

2.3.4.2 Formal education and the type of undergraduate curriculum

Formal education was reported to have an effect on the decision making process. However, there is a lack of research in dentistry to examine the effect of education. One study finding suggested that dentists from different countries, who received different education, tend to be varied with regards to decision about the need to extract a tooth (Zadik and Levin 2007). This finding may suggest the persistent effect of formal education on clinical reasoning skills.

The role of the different types of undergraduate curriculum in the development of clinical reasoning skills is controversial, and there is no consensus on the curriculum model that best facilitate the development of this skill. The effect of the different types of curriculum will be further discussed in Chapter 3.

2.3.4.3 Stage of progression in the course

It has been suggested that the stage of undergraduate study can affect the medical students' level of clinical reasoning skills. In other words, clinical reasoning skills develop throughout the successive progress of the students (Groves et al., 2003a, Da Silva, 2013). It has been found that dental students during early stages of their study may acquire extensive amount of biomedical knowledge, but they lack the effective application of this basic knowledge to clinical cases (Williams et al., 2014). The progressive nature of clinical reasoning skills development was described earlier; please refer to the '*Development of clinical reasoning expertise'* section on page 65.

2.3.4.4 Communication skills

In order to provide an acceptable level of patient care, biomedical and psychosocial skills should be combined. Integrating communication and clinical reasoning skills has been suggested to produce better performing students who understand and appreciate the importance of psychosocial and biomedical aspects of patient care (Windish, Price et al. 2005). It has also been suggested that communication skills training may improve students' clinical reasoning ability as this training would aid gathering more accurate information (including both biomedical and psychosocial history) by the students (Evans, Stanley et al. 1991). Obtaining a good grasp of the key features in the case *i.e.* gathering of information is a skill of paramount importance in making the right diagnosis. Incorrect or inadequate information about the case in hand inversely affects the diagnostic accuracy

(Omar and Akeel, 2010). It has also been found that, in seeking more information about the case, discriminatory and case specific questions posed by dentists were more important than the number of questions.

Because the development of communication skills can inform a more accurate diagnosis, these two skills are better taught in an integrated manner. It has been recommended that integrating the two skills could produce a better curriculum model which enhances the development of clinical reasoning and help the students to value the connection between the biomedical and the psychosocial aspects of patient care (Mullins et al., 2001, Windish et al., 2005), see '*Recommendations and suggestions to enhance the development of clinical reasoning'* section on page 94.

2.3.4.5 Knowledge base

Although a sound knowledge base of disease characteristics and treatment options is considered as an important factor in making the right decision, it is still insufficient as a basis for making a clinical decision. Many other factors are interacting during this process (Kay and Blinkhorn, 1996). Colleagues can be a valuable resource of information. It has been found that relationships with more experienced individuals and health professional staff can enhance the knowledge base of the practitioner and could in turn affect their problem solving ability and clinical reasoning. This was indicated by the findings of a study conducted in the field of physiotherapy (Smith et al., 2010). This finding was also supported in dentistry as dentists considered consultation with other health professionals as a valued source of information used during clinical decision making (Straub-Morarend et al., 2011).

2.3.4.6 Intuition

As mentioned earlier, it has been reported that dentists greatly rely on their intuition and personal judgement to reason through multiple options in order to achieve the desired outcome for a specific patient. Intuition was reported as a factor commonly affecting the dentists' decision making (Omar and Akeel, 2010, Elderton and Nuttall, 1983). Dentists use highly individualised scripts to diagnose caries (Bader and Shugars, 1997). Personal preference is found to affect their clinical decisions (Stempsey, 2009). An individual dentist's judgement and intuition can also make the dentist deviate from the ideal treatment plan or modify it depending on a patient-to-patient basis (Redford and Gift, 1997). However, reflection and discussion with dentists from other specialities has an effect for reconsidering the initial decision made by a single dentist (Youngson, 2011).

Although dentists vary in their clinical decisions, this variation was found to be consistent for individual dentist. This conclusion was suggested by the results of a longitudinal study conducted by Knutsson *et al* (2001), who found that there was no change over a period of ten years to dentists' decision regarding the prophylactic removal of third molars. The decision of these dentists seemed not to be affected by the pervading evidence supporting the non-cost effectiveness removal of third molars.

2.3.4.7 Clinical experience

Experience with real patients is essential to develop connections between the learned material and clinical presentations. These connections have been suggested to enhance the development of illness scripts, flexibility in reasoning and the effective utilisation of analytical and non-analytical strategies (Eva 2005, Bowen 2006).

Experience was shown to have a great effect on decision making in physiotherapy. It can change the practice of an individual rendering him/her more motivated to provide the best practice, reflective about own experience and more critical in selection of information to be added to own knowledge base (Smith et al., 2010).

2.3.4.8 Domain specific knowledge, speciality and professional experience

Dentists with different qualification in a specific field of dentistry tend to make different decision options. The level of education regarding a specific domain of dentistry has been found to affect the accuracy of diagnosis (Omar and Akeel, 2010, Akeel, 2008). Results of a recent study indicated that although dentists were varied in their choice of treatment options, dentists with similar qualifications had a tendency to choose similar treatment options (Lang-Hua et al., 2014).

Speciality of the dentist has been argued to have an effect on the clinical decision taken (Youngson, 2011, AlanI et al., 2011, Kay and Blinkhorn, 1996). A specialist tends to manage the cases supporting his/her field of speciality. Balto and Al-Madi (2004) argued that general dentist practitioners were more inclined to avoid retreatment of symptomatic endodontically treated teeth than an endodontic specialist. Furthermore, dentists who have a speciality scope of practice tend to rely more frequently on evidence-based resources when making clinical decisions than dentists from the general practice (Straub-Morarend et al., 2011).

In a study that compared decision-making of prosthodontists to that of general dentists and interns, it was suggested that prosthodontists generally put forward more possible treatment options for a special clinical case (the patient was missing two teeth). They also were more inclined to seek more information to confirm the recommended treatment choices (Omar and Akeel, 2010).

In physiotherapy, much work has been conducted to study the effect of various factors in the decision-making process. Prior professional experience, including academic experience, clinical experience, both behaviour and skills exposed to during clinical mentorship, clinical teaching of others and continuing education were considered as factors affecting the decision making process (Wainwright et al., 2011).

2.3.4.9 Evidence-based dentistry

It has been found that in order to support dental decision, dental practitioners use different information resources including evidence-based and non-evidence-based materials (Straub-Morarend et al., 2011). Discussion about the dentists view regarding the reliance on evidence when making clinical decision is included in Chapter 3.

2.3.4.10 Critical thinking

Critical thinking is a rich concept that has been developing throughout the past 250years. Contrasting concepts regarding critical thinking have been developed and expressed in the literature. In this section, a brief review of critical thinking and its relationship to clinical reasoning is provided without getting into the detailed concepts of this term.

As described by Pardamean (2012a) critical thinking is "*demonstrated by the individual ability to judge the soundness of information, assess conclusions, and make good inferences*". One of the definitions explaining this term is what was suggested by Scriven and Paul as "*the intellectually disciplined process of actively and skilfully conceptualizing, applying, analyzing,* *synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action"* (Critical Thinking Foundation, 2013). The importance of critical thinking for medical education has been reflected in the objectives of most schools as these are commonly directed towards educating students to be critical thinkers (Facione et al., 1991).

Critical thinking could be considered as one of the most important factors affecting the development of clinical reasoning skills, as it entails the examination of those structures or elements of thought implicit in all reasoning. These elements may include: purpose, problem, or question-at-issue; assumptions; concepts; empirical grounding; reasoning leading to conclusions; implications and consequences; objections from alternative viewpoints; and frame of reference. Critical thinking has two main components. These are: skill to generate and process information and believes, and the habit, based on intellectual commitment, of using this skill to guide behaviour. According to Glaser, critical thinking involves three main components, as follows:

1. An attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences
2. Knowledge of the methods of logical inquiry and reasoning
3. Some skill in applying those methods

Furthermore, it involves recognizing problems and finding workable means to deal with them via searching and gathering of pertinent information. This is generally done with the intention to recognize unstated assumptions and values, to comprehend and use language with accuracy, clarity, and discrimination, to interpret data, to appraise evidence and evaluate arguments.

A critical thinker is continuously engaged in efforts to examine knowledge in relation to the available supporting evidence that supports it (Critical Thinking Foundation, 2013). Certain characteristics are associated with a well cultivated critical thinker, as follows:

- raises vital questions and problems, formulating them clearly and precisely
- gathers and assesses relevant information, using abstract ideas to interpret it effectively
- comes to well-reasoned conclusions and solutions, testing them against relevant criteria and standards
- thinks open-mindedly within alternative systems of thought, recognizing and assessing their assumptions, implications, and practical consequences
- communicates effectively with others in figuring out solutions to complex problems

As suggested by Pau and Elder (2008), critical thinking is, in short, self-directed, self-disciplined, self-monitored, and self-corrective thinking. It presupposes assent to rigorous standards of excellence and mindful command of their use. It entails effective communication and problem solving abilities and a commitment to overcome our native egocentrism and sociocentrism.

From the above description, it could be concluded that there is a strong relationship between critical thinking and clinical reasoning. It has been suggested that critical thinking improves the students' ability to make decisions or draw conclusions to problems that may not always have a correct solution (Pardamean, 2012a). It was suggested that developing the skills for critical thinking could facilitate the development of clinical reasoning in medical students (Christensen et al., 2008). Glick (2010) has also suggested that fostering the skills of critical thinking would enhance the proficiency of clinical decisions in dental students.

The skill of critical thinking is commonly described as one of the competencies required for dental students in order to become dentists. Critical thinking by name was described and mentioned in the objectives of all dental curriculum documents for the dental schools involved in this thesis (King Abdulaziz University, 2012, School of Dentistry at the University of Manchester, 2013, Taibah University, 2012, University of Birmingham, 2014, University of Manchester, 2012).

Despite the fact that a study in nursing has considered critical thinking as being important to facilitate the development of clinical reasoning and predicts its level (Cerullo and Cruz, 2010). Another study found the opposite in medical students. The results of the second study stated that "*although some might consider clinical reasoning as a kind of thinking, it was shown that there is no statistically significant correlation between clinical reasoning and critical thinking as constructs*" (Ashoorion et al., 2012).

2.3.4.11 Moral development and confidence

Critical thinking was suggested to be enhanced in individuals who are more likely to think morally when doing a task. Moral development was also thought to be developing with age (Hong Kong Polythechnic University, 2014). A confident individual is likely to proceed with the decision-making process with little time spent worrying about the possible failure. Confidence was thought to be associated with expert practitioners. High level of confidence can enhance the problem solving ability (Smith et al., 2010).

2.3.4.12 Emotional intelligence

Emotional intelligence is defined as the ability to understand and manage oneself and others in addition to managing relationships (Stoller et al., 2013). This attribute has stimulated debate in the literature. Some of the researchers believe that it is a form of pure intelligence and a cognitive ability. Others have described it as a mixed intelligence of cognitive ability and personality traits (Stys and Brown, 2004). In addition to the suggested effect of emotional intelligence on many skills such as academic achievement, it has also been suggested that it has an effect on the development of the skills of clinical reasoning in medical students (Ashoorion et al., 2012).

2.3.4.13 Personality

Personality factors have appeared to play a role on both critical thinking and clinical performance in dental students (Chambers, 2009). However, although personality traits could affect the leadership style, they have no effect on clinical reasoning as suggested by Ashoorion *et al* (2012).

2.3.4.14 Problem solving

As mentioned earlier, problem solving and clinical reasoning have commonly been used synonymously in the literature. Many researchers and educators argued that clinical reasoning is a form of solving medical problems. For that reason, theoretically, any factors affecting problem solving would consequently have an effect on clinical reasoning.

However, it was argued that the statistical correlation between problem-solving, as a subscale of emotional intelligence, and the level of clinical reasoning is only 0.07. This could possibly indicates the weak effect of problem solving ability on the development of clinical reasoning skills as stated by Ashoorion *et al* (2012).

2.3.4.15 Ethical and legal guidelines

Dental students are taught to follow ethical and legal guidelines, and it was found that these guidelines may affect a dentist’s decision to extract. Broers *et al* (2010).suggested the use of a flowchart that integrates possible considerations to aid the dentist in making decisions in case there was a request by the patient which is not in harmony with ethical guidelines.

Dental ethics must be applied and ethical guidelines may also be incorporated and included in the context attributes, as described earlier. However, following these guidelines could also be a characteristic of the decision maker. Studies have highlighted the importance of following dental ethics when making a treatment decision. Development of treatment plan together with the choice of therapeutic methods should consider the patient's circumstances and desire alongside the dentist's decision, to provide the best option for the patient (Huff et al., 2008).

After discussing how clinical reasoning can be learned and the factors influencing its acquisition, the following section discusses teaching of clinical reasoning based on the dental and medical literature. It also describes strategies, suggested in the literature, to enhance learning of clinical reasoning by students.

2.4 How can clinical reasoning be taught?

The importance of teaching clinical reasoning is reflected in Marcum's (2012) view as "*If medical students are not taught how they should reason by setting explicit conditions, then they may develop poor reasoning skills implicitly*". Traditionally, more focus has been given to procedural techniques and precision of technical skills in dental curricula while little attention has been allocated to diagnostic skills (Crespo et al., 2004, Gowda and Lamster, 2011). Moreover, dental education has focussed on the isolated teaching of knowledge or teaching of knowledge in clinical contexts artificially created by teachers. This teaching approach may result in the difficulty of the effective integration and application of knowledge in real clinical settings and render the students less appreciative regarding the importance of biomedical science knowledge. The issue associated with the deficient application of biomedical knowledge in clinical settings indicated a gap between knowledge and applied reasoning in dental students (Williams et al., 2014). This problem is argued to be usually associated with the traditional dental curriculum, further discussion will be provided in Chapter 3.

Furthermore, formal teaching of treatment planning (an important component in the decision making process) has received little attention in the dental literature. This is reflected in the lack of consistent format being followed in the dental curricula regarding teaching and development of treatment plan for undergraduate students (Tokede et al., 2013).

In response to the deficiencies in the dental curriculum regarding teaching clinical reasoning, there have been repeated calls to enhance the level of critical thinking in both dental students and faculty members because critical thinking is considered as an important factor which influences the level of clinical reasoning, as mentioned above (Chambers, 2009). There have been also calls to examine the effectiveness of different teaching methods in enhancing the problem solving and clinical decision making abilities in dental students (Kay et al., 2001).

It is well known in medical education that knowledge base is important in making clinical decisions. However, the presence of sound knowledge base alone is not enough to make good clinical judgement. Although this fact is well known, clinical reasoning has been argued to be rarely taught in medical schools in formal teaching formats (Round, 1999). Clinical reasoning was commonly taught in case-based presentation focussing on generation of differential diagnoses and working on them to reach the final acceptable diagnosis (Thomas, 1992, Menahem and Paget, 1990). History-taking and communication skills are usually taught in the preclinical phase at undergraduate medical education, while the opportunity for students to be exposed to instructions for clinical reasoning is commonly provided during the following phase of clerkships. It is commonly thought that medical students spend a long time learning the signs and symptoms of disease and knowledge about diverse differential diagnoses, allowing less time for actual clinical experience. This in turn has led to underestimation of the importance of clinical training in teaching clinical reasoning (Norman et al., 2007). It has been argued that teaching the components of clinical reasoning separately in preclinical and clinical phases of the undergraduate medical education has argued to result in students who do not feel the important connection between communication and obtaining good medical information and not appreciating the impact of reasoning on communication, or even undervalue the psychosocial patient history (Windish et al., 2005). In response, it was suggested by Neufeld *et al* (1981) that problem solving ability is not a single skill that could be taught separately from other competencies, including knowledge application and evaluation of the obtained data together with the techniques used in history taking and physical examination and communication skills.

Until recently, medical schools rarely implemented formal teaching of clinical reasoning in their curricula (Felix et al., 2015). Berner *et al* in (Gale and Marsden, 1982) argued that the skill of diagnosis must be taught, and the assumptions underlying such teaching must be sound. It has been suggested that it would be wise for the medical educators to recognise and enhance the characteristics of clinical reasoning formally in their teaching. Medical teachers could facilitate the development of skills such as acquisition of knowledge and experience, and gathering of clinical data rather than focussing on problem-solving *per se* (Neufeld et al., 1981).

However, from my personal experience and the review of medical literature, it appears that teaching clinical reasoning is changing in current medical and dental education. The repeated calls for curriculum improvement, together with growing research in clinical reasoning, have resulted in greater understanding of the phenomenon of clinical reasoning and more appreciation of its importance. Trials and suggestions have been made to develop different teaching approaches and curriculum reforms in order to enhance the development of clinical reasoning skills. Ryan and Higgs (2008) argued that despite the broad acknowledgement of the role of clinical reasoning, the value accredited to it and the goal of many developing courses being explicitly directed towards developing the skills for clinical reasoning, there is often a lack of how this goal is to be achieved in a coherent and integrated manner in medical curricula. They also argued that even in Problem Based Learning (PBL) courses which generally provide more focus on developing problem solving abilities, there is still a need for more explication and realisation of educational principles and theories in curricula.

One of the efforts to develop medical school's curriculum, which I personally have come across, directed towards facilitating the development of clinical reasoning in medical students was presented at a seminar and workshop titled *clinical reasoning in undergraduate medical curriculum*. During this seminar schools' experiences, features of undergraduate curriculum and teaching strategies to enhance clinical reasoning development were presented and shared. Moreover, certain advice and strategies were suggested such as directing students towards clinical reasoning when discussing clinical cases and implementing early assessment of clinical reasoning. However, a conclusion was reached as despite all the efforts made towards fostering the development of clinical reasoning skills, results cannot be guaranteed and empirical studies are needed to support the effectiveness of such strategies (Seminar, 2012).

Some medical schools are incorporating specially designed courses to introduce the concepts of clinical reasoning and its strategies in order to promote the awareness of their students of the skills required for it. The University of Nottingham, for example, offers a course for the medical students early in their undergraduate study. During this course clinical reasoning is mentioned and diagnostic strategies are described for the students. The diagnostic process is described *e.g*. in cases with multiple hypotheses focus is given to the scientific evidence to support or reject these hypotheses, while not ignoring the less probable conditions which might in turn cause harm to the patient. Hypothetico-deductive model of clinical reasoning is also described in the course (Heywood, 2013).

Similarly in dentistry many schools incorporate elements of evidence-based dentistry in order to support critical thinking in the students *e.g*. the Dental Schools at Taibah University and the University of Birmingham, (participating in the current research) (Taibah University, 2012, University of Birmingham, 2014).

Beside the Hypothetico-deductive model of clinical reasoning, other theories of learning are also incorporated and form a base for teaching clinical reasoning in medical students. Dual process model incorporating system 1 and system 2 reasoning has been suggested to facilitate teaching of clinical reasoning and argued to have advantages over other models of clinical reasoning. Marcum (2012) suggested instructing the students to start by system 1 in order to assess patients' information and presentations. Then system 2 should be used to evaluate the rising hypotheses and to seek scientific evidence if required. Finally, he stressed on the importance of feedback in developing students' metacognition. He suggested that teaching clinical reasoning should start early in undergraduate medical curriculum by having courses to enhance the development of critical thinking in the pre-clinical phase. Students should also be trained to use the intuitive reasoning beside system 2. He argued that the use of this model in teaching clinical reasoning synergistically with metacognition enforcement could lead to faster and more accurate development of clinical reasoning in medical students.

Despite the consensus about the need for effective reform and development of the undergraduate medical and dental curricula to enhance the skills of clinical reasoning in students, best practice strategies to help students to acquire the skills needed for clinical reasoning remain a source of conjecture (Hendricson et al., 2006), and there is a considerable debate in the literature about the best educational strategies and philosophies to enhance clinical reasoning (Ryan and Higgs, 2008). It is concluded that it is hard to specify strategies in clinical teaching that best enhance the development of clinical reasoning skills. This has been considered, for long, a challenge in dental education (Wetmore et al., 2010).

2.4.1 Recommendations and suggestions to enhance the development of clinical reasoning in undergraduate medical and dental students

Some suggestions have been tested, mainly in medicine and to a lesser extent in dentistry, to examine the possible effect of certain educational strategies in fostering the development of clinical reasoning skills in students. Researchers have formulated recommendations that are argued to be helpful in the required development of the undergraduate curriculum. Some of these suggestions are summarised below:

- Confronting students with a large variety of examples can aid their problem solving ability (Eva et al., 1998). Providing students with a large number of similar clinical exemplars may facilitate the development of patterns and hence the development of system 1 reasoning which is important in clinical reasoning skills development, based on the dual-process model (Norman et al., 2007).

- Practice is required to gain experience which is required to develop students' clinical reasoning ability. Practicing with good role model of experts can also help to facilitate the development of clinical reasoning skills in students (Ericsson, 2004, Smith et al., 2010).

- Supervising clinical sessions are very important to foster the development of the skills required for clinical reasoning. Strategies have been put and suggested for supervisors aiming to encourage students to elaborate on their thinking and reasoning processes (Audétat and Laurin, 2010). Clinical teachers are responsible for promoting the development of these skills in students through facilitating the connection of clinical features and the basic knowledge, and assessing the level of its development throughout their clinical supervisions aiming to produce independent medical students in clinical settings (Irby, 1992, Zadik and Levin, 2007, Bowen, 2006, Cutrer et al., 2013).

- It is argued that practical experience would have the most powerful effect on the development of clinical reasoning skills in students especially when it is associated with reflection (Audétat and Laurin, 2010). When the teacher asks students to reason aloud during dealing with a clinical case, he/she is uncovering the reasoning process used by the learner and then he/she can guide the process (Bowen, 2006).

- Knowing that failure to correctly represent the patient's problem can generate random hypotheses depending on the isolated findings, teachers can encourage students to develop a single sentence summarising the case using abstract terms (Nendaz and Bordage, 2002, Bowen, 2006).

- Encouraging students to compare and contrast the diagnostic possibilities in relation to the obtained data from the specific patient could enhance the development of illness scripts (Bowen, 2006).

- As suggested by Bowen, teachers should encourage students to read through different clinical cases in a way that enhances their reasoning skill development. Students should read about no more than two diagnoses trying to compare and contrast their features. Sharing of students' understanding after reading can also encourage their skill development (Bowen, 2006).

- Teaching Strategies for comparing and contrasting is argued to help in the development of clinical reasoning. Novice students usually tend to generate a random list of diagnostic possibilities, teachers are required to ask students to priorities their possibilities and justify their choices. By doing this, students can develop their own illness scripts relating specific features to a possible case diagnosis (Bowen, 2006).

- Any attempts to facilitate the development of clinical reasoning skills in undergraduate students would fail unless we consider the process of transfer. A reductionist view of this process concluded that it is a difficult mental process which enables the students to recall their basic knowledge and apply it to the current practical situation (Eva et al., 1998). Therefore, it is more important for medical teachers to supply information for students in a way that enhance retrieval and application of knowledge rather than the quantity of knowledge. In other words, stressing and emphasis on certain knowledge and its importance can aid the transmission of knowledge and its organisation from the (expert) teacher's mind to the (learner) student's mind (Cutrer et al., 2013).

- Illness scripts, however, cannot be linearly transmitted from teachers to learners. To enhance the development of scripts, teachers may use prompts and questions in order to stimulate the reorganisation of knowledge and facilitate the development of individual scripts by the students (Cutrer et al., 2013).

- Problem presentation should be promoted in students. As described earlier, novice students tend to develop many hypotheses for each isolated finding in the case. Summarisation of the patient information and presenting the problem in a confined and informative sentence should be promoted. However, teaching of problem representation skill should be associated to clinical settings in order to promote clinical reasoning. In this way the connection will facilitate retrieval of related information from memory (Nendaz and Bordage, 2002, Bowen, 2006).

- Providing cognitive feedback is frequently suggested to foster the development of students' reasoning skills. This feedback should be formative and detailed. Teachers should explain their feedback illustrating the relativeness of specific possible diagnoses together with the key features that support or reject these possibilities (Marcum, 2012, Bowen, 2006).

- The use of virtual patients was argued to aid the development of clinical reasoning in medical students (Bateman et al., 2012).

- It has been recommended that discussions are provided for diagnostic reasoning and diagnostic errors providing more focus on the development of diagnostic skills in students (Gowda and Lamster, 2011).

- Reflective blogs are suggested to increase the level of reflection and in turn the critical thinking in dental education (Wetmore et al., 2010). Reflective practice has been argued to add more value to the dental curriculum to facilitate critical thinking (Chambers, 2009).

- Incorporating Evidence-based dentistry was also suggested to foster and decrease time and effort required for dental decision making (Stafford, 2014).

- Specific curriculum reform namely *blended learning* has been suggested to facilitate the development of critical thinking in preclinical dental education. In this approach, students are exposed to integrated classroom experiences and online learning experiences having elements of personalised reflection (Faraone et al., 2013).

- Dental demonstration is considered an important part of dental education, especially in the traditional approach of pre-clinical and clinical phases of dental curriculum. A new strategy has been tested and resulted in increasing the level of clinical reasoning in dental students. An instructor-led seminar that allows students to follow and discuss the broadcasted procedures conducted by the instructor was argued to be superior to the traditional way of dental demonstration. This procedure can increase the integration of knowledge to practice by the students (Rystedt et al., 2013).

- Small group teaching has been suggested to provide high levels of discussion opportunities for students helping in integration of biomedical knowledge and clinical context (Patel et al., 2005).

- Faculty training programs were also suggested to facilitate and enhance clinical evaluation of students competence in ethical reasoning (Christie et al., 2007).

- Audétat *et al* have suggested a framework outlining clinical reasoning difficulties encountered by medical students during the different steps of the reasoning process. This framework is claimed to help medical teachers to identify certain types of difficulties in order to deal with them and enhance teaching of clinical reasoning (Audétat et al., 2013). Students could be helped to develop their clinical reasoning skills when educators can identify at which point a given learner's reasoning is breaking down (Cutrer et al., 2013).

- A recent study suggested the use of self-explanation while diagnosing clinical cases to foster the development of clinical reasoning skills in medical students. These skills are argued to be further reinforced by listening to examples of self-explanation by residents in addition to the use of prompts to enhance active learning of clinical reasoning (Chamberland et al., 2015).

Effective teaching of clinical reasoning is summarised by Ryan and Higgs. They suggested that methods of learning about reasoning should be applied at three levels: prospective reasoning, reasoning in action and retrospective reasoning in order to facilitate clinical reasoning learning in reflective and reflexive learning opportunities throughout health science curricula.

Table 2:4 illustrates and compares the different teaching methods suggested (Ryan and Higgs, 2008).

Table 2:4: Methods of learning about reasoning at prospective, in-action, and retrospective levels, adapted from (Ryan and Higgs, 2008).

Methods to promote:	Advantages	Disadvantages
Prospective reasoning -Guided observation (viewing videos/actors/patients/ documents) -Uses students' experiences/ stories -Uses provocative readings	Learner focuses their thinking on a topic (priming the mind) Learner becomes aware of their personal body of knowledge - what they know and what they need to know in a general sense so they can act on this knowledge Learner becomes more aware of own biases, values, attitudes to be discussed Learners' reasoning can be challenged in a safe environment	The immediacy of the situation is not apparent The learner might still be really unaware of the recipient's feelings and actual conditions so their reasoning is not contextual but hypothetical As this experience is one-sided plans are not developed together as in client-centred practice
Retrospective reasoning - Tape-recording thoughts, memories and accounts of	Less effort for the learner than some other methods	Learner feels foolish as most people are very unused to this

situations alone or in an interview situation - Talking with another person	Captures immediate thinking - free thinking There is a record for further examination Gaps in learning and ability are identified when the script is transcribed Voice and story-telling acts as a trigger for other thoughts and memories The learner's tone of voice and mood is apparent Challenging questions need to be done in a particular way The other person can bring in related ideas you had not thought of	Learner feels disorganized unless they can have prompt notes There are no visual prompts The process can appear to be too long The tape is open to legal interpretation You need privacy Others may interrupt the learner's thought patterns with questions Thoughts are not captured anywhere so there is no record to go back to Others may interrupt with different thought patterns or their own stories The learner can feel inhibited Many thoughts are lost in writing as each person edits their thinking

- Writing retrospectively and reflectively	You do not need any equipment Sometimes it is comforting that others think the same way Logical and ordered process - you see an order and an image Free flow writing can capture ideas People are used to writing things down Learner may feel less inhibited than in other methods - may depend on audience Learners have time to review their ideas Learners can identify links between ideas	Learner may feel lazy and not put in the necessary details Writing takes too much time Writing must be legible Writing is open to legal interpretation The learner may be very selective about what they write

2.5 How can clinical reasoning be assessed?

In the previous section the teaching of clinical reasoning was discussed. Teaching is usually followed by assessment in order to ensure that students actually acquire what they need to reach as a result of the provided teaching opportunities. There are various methods and tools for assessment applicable for medical students. Most of these different tools are also in use for dental students. In this section, the different methods to assess clinical reasoning are discussed.

Attempts to assess clinical reasoning began in the 1960s and 1970s (Amini et al., 2011, Van der Vleuten and Newble, 1995). Traditionally, there was an argument suggesting that diagnostic accuracy could only be determined by the presence of sound knowledge. Therefore, assessment of clinical reasoning was mainly directed towards assessing knowledge base information. However, this assumption can be challenged by the fact that there are other factors affecting the development of clinical reasoning and that the phenomenon of clinical reasoning involves multiple skills, as described earlier in this chapter.

The basic skill for clinical reasoning was commonly assessed through ward rounds, viva examination and practice attachments. These tools are generally argued to be unstructured and to have a low level of standardisation. Moreover, they may be biased in case selection, being subjective and lacking the inter-rater reliability (Newble et al., 2000). Furthermore, these measures assess only the outcome *i.e.* the end product of clinical reasoning (diagnosis and management) rather than the process itself (Groves et al., 2002). There is a great difference between the *process* and the *outcome* of clinical reasoning and the same should be applied to its assessment.

It has been suggested that assessing problem-solving ability should involve a concurrent assessment of other related skills and abilities such as knowledge application, selection of data from the available information and evaluating the need for more data and history-taking in addition to the communication skills. We considered most of these skills when we created our assessment tool described in Chapter 4.

Medical curricula have been developed to teach problem-solving skills and great effort has been expressed by medical schools towards developing instruments to measure this ability in medical students (Neufeld et al., 1981). Following the development in clinical reasoning research there was a concurrent development of the tools for its assessment with different levels of validity and reliability. Despite the fact that there was a growing attention given to clinical reasoning research in medicine and other health sectors, especially nursing, there is still a lack of consensus regarding the best way to assess this important skill. This was partly caused by the underlying contrasting epistemological views and related conceptual frameworks (Durning et al., 2013).

Epistemological views and their effect on clinical reasoning assessment approach were previously illustrated in Table 2:1 on page 35. The current section presents most of the different tools used, in the literature, to assess clinical reasoning focussing on their most important features rather than getting into much detail.

2.5.1 Qualitative assessment of diagnostic ability and clinical reasoning

For the purpose of research in medical education qualitative studying of the process of clinical reasoning was common in order to get a deep understanding of this process. Stimulated recall, think-aloud and protocol analysis have been used to get access to the mental processes taking part during reasoning (Psychology Faculty at Florida State University, 2013). However, this type of assessment is not intended to formally assess students' clinical reasoning ability in medical or dental undergraduate education; instead it is helpful for research purposes. Qualitative analysis of clinical reasoning will be further discussed in Chapter 5.

2.5.2 Multipurpose assessment tools

2.5.2.1 Objective Structured Clinical Examinations (OSCE), Multiple Choice Questions (MCQ), Short Answer Questions (SAQ)

OSCE, MCQ and SAQ are assessment tools commonly used in medical and dental education. They are not solely designed to assess clinical reasoning; instead they are commonly applied to test other skills beside knowledge base. OSCE was the preferred type of assessment for the problem solving skills in the late 1990s. This is because of its ability to sample a large spectrum of performance in a manageable period of time (Eva et al., 1998). However, it has been argued that OSCE has limited validity when it is applied for the assessment of diagnostic thinking (Ber, 2003).

MCQs are commonly used in assessment of medical and dental students. This type of questions can be formulated in a case-based format supplemented by stimuli such as dental chart or x-ray film. It has been argued that MCQs can be used to assess problem solving ability in dental students if properly structured. Advantages include the ease of construction and the objectivity of marking. However, their low fidelity and susceptibility to measurement errors such as guessing are considered among their disadvantages.

SAQs can be used to assess clinical reasoning in dental students when they are asked to develop a treatment plan for dental cases or to provide differential diagnoses for clinical cases. However, SAQs only assess the product of the reasoning process and rating could be affected by multiple sources of errors (Kramer et al., 2009).

2.5.2.2 Assessment by observation

Observing students' performance when they deal with clinical cases, mostly in clinical settings or simulated settings, is a method used in the assessment of undergraduate dental students' critical thinking and problem solving ability. Other skills can also be assessed, such as communication and professionalism. However, the subjectivity of rating could be a major disadvantage commonly associated with this type of assessment (Kramer et al., 2009).

2.5.3 Purposely designed clinical reasoning assessment tools

2.5.3.1 Test of Diagnostic Skills (TDS)

This test was developed by Rimoldi in 1955 aiming to focus on the process of problem solving rather than the products. This can be obtained by letting the subject ask questions, which he/she feels are important to reach a diagnosis. The number and the order of the asked questions are considered in the analysis, in addition to a choice of not asking any questions (Rimoldi, 1961).

An examinee initially receives basic information of the clinical case, which is usually listed in the hospital admission chart. Then he/she may decide to ask questions about the case in order to reach a diagnosis. Questions are presented in cards which have the answers. The participant may ask as many questions as required until he/she decides to terminate the test. Performance of each examinee is then evaluated against the group norms as well as against 'intrinsic' difficulty of each problem.

TDS may provide useful information on how physicians and medical students use information to reach diagnoses. It could be used to evaluate the information requested by physicians and medical students during their diagnosing process, the order in which this information is requested and exploration of clues and testing of diagnostic hypotheses. However, this assessment method has been criticised for its deficient validity. In addition, scoring scale used in this test has argued to be somewhat sophisticated, which further adds to its disadvantages (Rimoldi, 1963).

2.5.3.2 Patient Management Problems (PMPs)

This assessment type was first developed by McGuire and Babbott in 1967. The test includes a series of branched patient problems. These problems require sequential analysis and final decision making. PMPs creators claimed that this type of test is suitable for either individual or group administration and can also be marked electronically.

PMP was argued to be one of the most popular tools commonly used to assess clinical reasoning. Its claimed advantages include high authenticity and face validity.

However, after its wide use in medical education for the assessment of clinical reasoning, PMPs have been mostly abandoned in medical schools nowadays. This was because some disadvantages are encountered when using PMPs as a tool for clinical reasoning assessment. These disadvantages include: very low reliability, content (case) specificity, the time required to reach an acceptable level of reliability (many hours of testing), its scoring system (often focused on data gathering rather than the ability to make appropriate decisions), its ability to discriminate between practitioners with different levels of experience (which is low), and the absence of a gold standard. Finally, scores obtained from PMP are positively correlated to that obtained from knowledge based exams, thus Farmer and Page has argued that this test does not add to testing of clinical reasoning (Farmer and Page, 2005, Schuwirth, 2009).

2.5.3.3 Key Features Problems (KFP)

This test was first created in response to tackle the problems associated with PMP. Bordage and Page (2005) introduced the term key feature in 1987, as they believed that in every clinical case there are few unique elements which are the basis to reach the appropriate diagnosis This type of test is only concerned with testing a critical step, namely the students' ability to identify the key features in the presented cases. In this case a large number of clinical cases can be included in the test. This test can be delivered in both written and computer based formats.

This tool allows the selection of more than one correct answer, which could be considered as an advantage over MCQs, and more similar to reality. Another purported advantage is that KFP maintains the longitudinal nature of PMP in following clinical problems through different stages which also resemble the real clinical case and it is similar to long essay. On the other hand, an acceptable level of reliability (Cronbach's alpha value of 0.80) can be reached only in four hours of testing (Farmer and Page, 2005).

2.5.3.4 Diagnostic Thinking Inventory (DTI)

This type of clinical reasoning assessment consists of a self-reporting questionnaire. The original test consists of 65 items, and each item contains a stem followed by a 6-point semantic differential scale (Bordage et al., 1990). DTI was developed in response to the tradition of assessing clinical reasoning in a Hypothetico-deductive model way with its associated variables of data acquisition, hypothesis generation, data interpretation, and hypothesis evaluation. The other model of diagnostic ability assessment was commonly through the knowledge-based model. This model focuses on the availability of knowledge and its organisation in the memory. Recognition of meaningful information, definition of clinical data and access to knowledge structure in memory are all variables associated with this model.

However, Bordage *et al* (1990) have identified some variables through their research into diagnostic ability. They considered the ability of the clinician to identify personally relevant items of information as a very important step in diagnosis. They called these 'forceful features'. These features act as a key to particular memory structures and lead to particular interpretation of information. These features then have been either supported or refuted by the knowledge content and organisation in memory. DTI was designed to test two aspects of diagnostic thinking: the flexibility of thinking and knowledge organisation.

The latest format of DTI is composed of 41 items. Each item contains a stem and two opposing statements. The student needs to choose a level on a six semantic scale which represents the position on a continuum between the two statements. Marks are calculated based on the proximity of the chosen point to that of experts.

DTI is designed to assess reasoning style. Rather than having clinical realism this type of testing directly evaluates the reasoning process by evaluating the examinee's clinical reasoning style and attitudes (Groves et al., 2002).

It has been argued that DTI's reliability, indicated by the value of alpha coefficient for internal consistency of 0.83, is acceptable and able to discriminate the level of experience in both individual and group settings. More advantages have also been claimed for DTI, including its ability to measure the effects of specific educational interventions (Round, 1999). However, it was criticised for being a self-recorded evaluation by having the element of bias (Groves, 2002).

2.5.3.5 Comprehensive Integrative Puzzle (CIP)

This assessment tool was developed by Ber in 1995 in response to the difficulty encountered by medical students when they move from the pre-clinical phase to the disease oriented clerkship rotations and finally to patient oriented clinical practice (Ber, 2003). It consists of a complex crossword puzzle with columns of clinical vignettes and the rows contain the different possible diagnoses.

Ber (2003) argued that this assessment tool is highly acceptable by both students and teachers in medicine (Manzar and Al-Khusaiby, 2004). Despite its original aim, for summative assessment of medical students in the system integrated course-equivalent to year three and four, it has been argued that it could be also used to assess students' performance at every stage of their training, residency or during their continuous medical education programs.

In his description, Ber concluded that CIP is similar in concept to the extended matching assessment described by Case and Swanson (Case and Swanson, 1993), but in a more pleasant form to the students (Ber, 2003).

CIP is similar to a crossword puzzle. The typical format of it consists of a puzzle grid. The first column of the grid is a list of diagnostic entities, *e.g.* unstable angina, myocardial infarction *etc*... The remaining columns presents different sections where the examinee needs to fill into the cells choosing from a multiple choice pool of options indicated by letters (*a-f*) for the most simple CIP and (*a-z*) for more complicated forms of the test. The completed puzzle should have horizontal rows of different coherent medical cases. Students can choose each letter options once only, thus the examinee may get the benefit of default completion of the cell and receive bonus mark which differs according to the number of columns and the number of choices.

Scoring is done through an optical reader answer sheet, which gives prompt feedback which can be helpful for students. The horizontal scoring assess the examinee integrative ability (diagnostic thinking, clinical reasoning), and the vertical scoring reflects the student's mastery of the various disciplines. To pass the test student needs to obtain at least 60% vertical score and 60% horizontal score (Ber, 2003), (see Figure 2:6 for an example of answering sheet).

Student's name _______________

Student's number _______________

Matching columns

Diagnosis	I: Medical history	II: Physical Examination	III: Chest X-ray and ECG	IV: Laboratory and other tests	V: Treatment and follow-up	VI: Pathology
Unstable angina	1(d)	2(c)	3(c)	4(c)	5(d)	6(c)
Myocardial infarction	11(a)	12(a)	13(a)	14(a)	15(c)	16(a)
Rheumatic mitral stenosis	21(b)	22(d)	23(b)	24(d)	25(b)	26(e)
Acute pericarditis	31(f)	32(e)	33(f)	34(f)	35(e)	36(f)
Infective endocarditis	41(e)	42(f)	43(e)	44(e)	45(f)	46(b)
Hypertrophic cardiomyopathy	51(c)	52(b)	53(d)	54(b)	55(a)	56(d)

Figure 2:6: An example of answering grid for the CIP, source: (Ber, 2003).

The claimed CIP advantages include the advantage of integrating biomedical disciplines and clinical reasoning for enhanced learning.

This type of assessment is argued to be more effective in knowledge retention than other assessment types in which separation between various disciplines is the main feature. On the other hand, the difficult and the time consuming preparation for the test is considered among its disadvantages (*ibid*).

2.5.3.6 Script Concordance Test (SCT)

As mentioned above, testing of problem solving ability was commonly carried out by assessing the biomedical science knowledge base. MCQs and oral examinations (viva) were the commonly applied approaches for this type of assessment. Charlin and van der Vleuten (2004) disagreed with using MCQs, with well-defined answers to well defined problems, for testing reasoning in a clinical encounter. In a real clinical situation not all data are available to solve the problem and these data should be gathered in order to formulate the problem and then to solve it. Furthermore, in real clinical encounters, most medical problems are often ill-defined and uncertain (Fox, 2000). The use of oral examination in testing clinical reasoning has been unsupported. Although it can test professional knowledge, but it is usually impossible to standardise the scoring objectively and can be time consuming and not applicable for large number of examinees or varied examples of clinical conditions (Charlin and van der Vleuten, 2004, Van der Vleuten and Newble, 1995).

SCT is one of the innovative tools designed to assess clinical reasoning in undergraduate, postgraduate or continuing medical education (Charlin et al., 2000a). It was developed based on the theory of cognitive expertise, (described earlier, see page 65) which describes the variation between experts in solving clinical problems (actual or simulated) as being a result of illness scripts that have been shaped through individual training, experience and clinical exposure (Charlin et al., 2000a, Van der Vleuten et al., 2008).

Charlin *et al* (1998) described the nature of most clinical cases as being ill-defined and not necessarily having a straightforward algorithmic solution, and that the diagnostic skills are based on tacit knowledge which cannot be easily evaluated via the use of multiple choice questions.

SCT is used in medical professions to assess clinical reasoning competencies and specifically the ability of information interpretation in case of uncertainty. The response format of this test resembles the way information processing happens in the brain in case of challenging problems as described by the concept of script theory from cognitive psychology (Charlin et al., 1998, Lubarsky et al., 2013). With the assumption first made by Elstein *et al* that evaluation of clinical reasoning skills should be done by comparing the performance of medical students to that of experts in the way they deal with clinical cases, this test follows this concept. Although scripts of the experts are different in details, depending on the subject's experience, they are similar in the essential elements.

The SCT scoring system is designed to measure the difference between examinees' scripts and that of experts (Charlin et al., 2000a). The test consists of clinical vignettes, which are described in a few sentences, in simple or detailed description. Selection of test item format depends on the objective of the assessment and the types of skills to be tested (diagnosis, investigation, or treatment measurement of attitudes). For each vignette items are grouped by format. The end product is a test item consisting of three different parts. The first part includes diagnostic hypothesis, investigative action or a treatment option based on the clinical case presented in the vignette (presented in the form 'if you were thinking of…’). The second part presents new information which might or might not affect the original choice of hypothesis, investigative action or treatment choice as a result of physical examination sign, a pre-existing condition, an imaging study, or a laboratory test (presented in the form’ and then you find...’) . The final part of the test consists of a five-point Likert-type scale (presented in the form of ‘this hypothesis becomes…’). This scale usually ranging from -2 to +2 (Lubarsky et al., 2013). Construction of the items follows the key feature approach, described above.

The scoring system used follows the aggregate scoring method, which was proposed by Norman (Norman, 1985) and Norcini *et al* (Norcini et al., 1990) in order to address the important issue of variability among experts when they reason on ill-defined problems. It was found, in a study conducted by Chalin *et al* (2002) that the aggregate method is superior to the consensus method in discriminating between experts’ and students’ reasoning in case of uncertainty. The credit for each answer reflects the number of panel experts who supplied that answer divided by the modal value for the item (Charlin and van der Vleuten, 2004). As described by Charlin and van der Vleuten “for example, if on an item six panel members (out of ten) have chosen response +1, this choice receives 1 point (6/6). If three experts chose response +2, this choice receives 0.5 (3/6), and if one expert chose response 0, this choice receives 0.16 point (1/6). The total score for the test is the sum of credits obtained on all items. This score is then divided by the number of items and multiplied by 100 to get a percentage score”. Examples of the SCT format were presented in our clinical reasoning test, (see Appendix 2).

The important feature of this type of assessment tool is that each item is built in a way that reflection is required to answer it, in addition to the fact that these items are individually created independent of the other items, which results in preventing cumulative errors. Moreover, it is clearly presented in the information given to the examinees that each test item is independent of the others. Usually, data from 5-10 experts are used to set the scoring scale. Scoring is weighted by the degree of agreement between the experts.

SCT is argued to have multiple advantages. It has been argued that it is both valid and reliable assessment tool. A value of Cronbach's alpha coefficient of 0.80, which indicates an acceptable reliability of a test, can be reached in one hour or less of the test. Moreover, it needs relatively modest resources for its creation (Charlin and van der Vleuten, 2004).

Other advantages are also claimed for the scoring system. One of those advantages is that once the response grid is set, there is no answer interpretation needed and the test is standardised and machine-scorable. Construct validity, reliability and feasibility were claimed to have been supported by a substantial body of research in different health professions and across a spectrum of health care education including undergraduate, post graduate and continuous professional development education (Lubarsky et al., 2013). Another advantage of the scoring system is that since there is no single best answer, the test could be used in test-retest situation. The test could also be used as a viable educational tool if there were exchange of information through discussion between experts and examinees. Finally, the test could be useful in situation where there is no consensus among the experts (Charlin et al., 2000a, Charlin et al., 2002).

Moreover, a study conducted in 2012 has argued that SCT is both valid and reliable in measuring intra-operative clinical reasoning among surgical residents on a national level. SCT was able to differentiate between junior and senior residents. This study suggested that SCT can be developed to assess clinical reasoning skills in high-stakes national examinations (Nouh et al., 2012).

In a study conducted by Humbert *et al* (2011b), it was found that SCT can differentiate between pre-clinical medical students and fourth year medical students from two US medical schools and that this test can be a valuable tool in assessing problem solving ability in competency evaluation even in the beginning years of medical education. In another study, they also examined the convergent validity of SCT by matching the results of SCT in emergency medicine to the results obtained from other US clinical reasoning examinations for the same subjects. Results showed significant correlations. The findings of this study suggested that SCT could be an efficient tool to measure clinical reasoning skills in cases of uncertainty. It also showed great resemblance to the real world clinical practice where ambiguities are common (Humbert et al., 2011a).

Lubarsky *et al* (2011) conducted a study to test the validity of SCT. In their study they reviewed all the published research regarding the validity of SCT. They concluded that there is a general agreement in the published research to the usefulness of using SCT to assess the interpretation of clinical data under conditions of uncertainty. However, there was argument about the validity which requires verifications in different contexts and particular types of CRTs. A call for more research regarding the effects of SCT on teaching and learning was raised. Future research to examine how SCT can integrate with other assessment tools in comprehensive testing was also raised in their study. We have examined this element in the current research, (please see Chapter 4).

Fournier *et al* (2008) have specified that the panel of experts should be made up of physicians with good overall clinical experience in the field rather than experts from narrow parts of the field. Characteristics of the expert panel are not quite firm, reflecting uncertainty in what constitutes expertise as described by Norman (2005). However, as a guideline Lubarsky *et al* (2013) have suggested inputs from ten experts in lower-stakes and fifteen for high-stakes examinations.

Furthermore, unlike MCQ and essay questions, SCT is not testing the amount of knowledge. Rather it is concerned with the structure and organisation of knowledge *i.e.* how knowledge is structured and linked in the mind when confronted by an authentic clinical case. This means that SCT is only testing one outcome of clinical reasoning, namely information processing in case of uncertainty. SCT offers hypotheses in the first column, and data gathering in the second column. Therefore, SCT is not testing hypotheses generation or data selection from the case description. It only assesses the interpretation of data and hypothesis evaluation phases of the clinical reasoning process.

In addition, Lineberry *et al* (2013) have challenged the suitability of SCT for high-stakes testing because of its deficient levels of validity. They have also criticised the aggregate scoring method used in SCT.

2.5.3.7 Clinical Reasoning Problems (CRP)

This type of assessment tool is a paper-based test designed to evaluate first stages of clinical reasoning *i.e.* identification and interpretation of relevant information from the presented clinical features and hypotheses generation. It reflects reasoning ability rather than diagnostic accuracy (Groves, 2002).

Examinees are asked to identify the key features in the clinical scenario that either support (+) or do not support (-) their possible diagnoses. They are also asked to weigh and prioritise these features according to their importance in their diagnostic decisions. Scores are then compared to a panel of experts.

Groves *et al* (2002) claimed that CRP is reliable for assessing clinical reasoning in variable levels of experience. They also indicated the suitability of this test to be used to monitor students' clinical reasoning throughout their study and also to evaluate curriculum development.

2.5.4 Other methods to assess clinical reasoning

Computer assisted assessment tools are argued to add fidelity to the assessment of clinical reasoning. Computer-based clinical scenarios are argued to assess students' ability to apply biomedical science knowledge in clinical cases, and hence assessing their diagnostic ability and treatment planning. Simulated clinical cases can be supplemented by visual and audio stimuli. This can be highly applicable to dental students because common scripts are mainly visually triggered in dental students (Khatami et al., 2011). However, the use of this type of assessment in the formal assessment of students' clinical ability could be expensive and time consuming (Kramer et al., 2009).

From the above presented different types of assessment applicable to clinical reasoning we can understand that the variability of these tools may reflect the complexity attached to this skill. Furthermore, these different assessment tools have been created following specific theoretical frameworks suggested for clinical reasoning, (see the '*theoretical concepts'* section on page

28). Some of them have even been developed in response to deficiencies associated with other types of assessment. Creators of these tools supported their mostly contrasting views and interpretations of clinical reasoning.

In conclusion, there is no single tool or measure that can best assess the clinical reasoning process or end product that is valid and reliable. Instead, one should carefully consider the aim, objectives and reasons for this assessment (Groves, 2002). Moreover, Schuwirth (2009) concluded that because clinical reasoning and problem solving are highly domain specific and are not generic traits, the current methods for assessment are likely to fail as they rely on short cases and asking the students for essential decisions and are generic in nature.

Assessing students for clinical reasoning should come from many sources because it consists of multiple traits such as knowledge, skills, problem solving etc., and each trait is best assessed by a specific tool. Multisource assessment was also suggested to assess undergraduate dental students' skills including critical thinking and problem solving (Kramer et al., 2009).

2.6 Clinical reasoning research in dentistry

Earlier in this chapter, we discussed the meaning of clinical reasoning, its development, different factors affecting its acquisition and how it has been taught and assessed. Our current view of clinical reasoning has resulted from ongoing research of this phenomenon. All of the presented information came from the joint effort of researchers, although there is no consensus in the literature about the best way to define clinical reasoning, the best model to explain it or best strategies to teach and assess it.

Ryan and Higgs argued that as with any new corpus of work, many researchers critique the work of others and try to emerge with different explanations to support their views. This has happened in clinical reasoning research. However, some researchers have depended on and integrated the previous work of other researchers in the field (Ryan and Higgs, 2008). In this section we intend to describe the history of clinical reasoning research in dentistry and its current status concluding by the calls for more research in order to support our aim and objectives.

In general, research in clinical reasoning began with observation of novices and experts in action. It involved analysis of their problem solving steps and accuracy. It also speculated the assessment of dysfunctional behaviours and the cognitive process involved in clinical reasoning (Hendricson et al., 2006). Most of this research was conducted in medicine and nursing and, as stated earlier, dentistry was falling behind the biomedical science in regards to research of clinical reasoning (Maupome, 2000).

Currently, there is deficiency in the dental literature regarding clinical reasoning research, as only a few studies have described clinical reasoning (Maupome et al., 2010). Researchers have stressed mainly on the quality of performance (Flack et al., 1996), the use of algorithms in an attempt to enhance the reproducibility of clinical management (Espelid, 1986, Kay and Nuttall, 1994), or described the diagnostic action of dentists during diagnostic management (Bader and Shugars, 1997).

Clinical reasoning research has started in dentistry since 1970s, when it was suggested that dentists should or could improve their approach to problem solving. Since that time multiple conceptual explanations have been formulated and suggested, including decision analysis, preference-based measurement, standard gambling technique, rating scales, game theory, time trade-offs, quality-adjusted life (tooth) years, and Bayesian-based utility measures. They are collectively called medical decision theory

(Khatami et al., 2008b). However, using Bayesian rules to mathematically calculate the probability and eventually reaching a decision not only depend on extensive knowledge of all the possible alternatives and their consensus, but also occasionally conflicts with a clinician's ethical principles or with a patient's preferences for treatment (Patel et al., 2002, Khatami et al., 2008a).

In 1993, Bradley (1993) argued that using a decision tree in medical decision making requires a degree of artistry and expertise. It is not a straight forward mechanical or automatic process, rather some creativity is needed to formulate a decision tree. Consequently, little support for the development of decision support systems has been given to Bayesian rule in dentistry (Khatami et al., 2008b).

In response to the unsuitability of medical decision theory for dental decision making, Bader and Shugars (1997) suggested a conceptual model for decision making related to dental caries in 1997. However, this model only described experts' decision making and was only applicable to caries.

Another decision model was suggested by White and Maupome (2003) to help dentists make diagnosis and treatment planning and reduce errors for dental caries and periodontal diseases. In this model the clinical case features are broken down into components. These components are individually analysed then recombined to suggest a preferred strategy, (see Figure 2:7). However, this model cannot replace the reliance on clinical judgement and experience in making clinical decisions. Rather, it can be useful for educational and training purposes.

In the 1980s, a number of computer-assisted systems for diagnosis and treatment planning appeared specifically in different dental specialities such as orthodontics, prosthodontics and oral medicine (Khatami et al., 2008b). Some of these systems have then been suggested to be developed to more sophisticated systems such as the orthodontics computer assisted decision system based on the theory of fuzzy logic (AkÃ§am and Takada, 2002). With the recent development in clinical decision making there is an increasing awareness of the importance of language, symbols and semantics and these are involved in intelligent decision aid systems. Computation of numbers in Bayesian theory is replaced by computation of symbols, which represent uncertainty in clinical situations, heuristics, or trial-and-errors, and the structure of knowledge and perception (Sadegh-Zadeh, 2001, Zadeh, 2008).

However, fuzzy logic[2] is not used in dentistry (Khatami et al., 2008b). The advance in dental clinical reasoning is also presented in the development of an intelligent tutoring system for clinical reasoning skill acquisition in undergraduate dental students (Suebnukarn, 2009), this will be further described in the next chapter.

In the 1990s clinical reasoning in dentistry was largely under the influence of the Hypothetico-deductive (H-D) model of information processing theory and it served as a basis for problem-based learning in medicine and dentistry. However, (H-D) model is limited when it comes to explain the reasoning of dental students when dealing with routine dental problems such as the management of caries. Instead, these students use a combination of (H-D) and pattern recognition approaches (Maupomé and

[2] Fuzzy logic is a well-structured system with a solid mathematical foundation and can be used in decision making. In a fuzzy set, an element is included with a degree of truth normally ranging from 0 to 1. Fuzzy logic models allow an object to be categorized in more than one exclusive set with different levels of truth or confidence. Fuzzy logic recognizes the lack of knowledge or absence of precise data, and it explicitly considers the cause-and-effect chain among variables, source: SHANG, K. & HOSSEN, Z. 2013. Applying Fuzzy Logic to risk Assessment and decision-making. Available: file:///C:/Users/mcxen3/Downloads/research-2013-fuzzy-logic.pdf [Accessed 5/2/2015].

Sheiham, 2000) or caries scripts to make diagnostic and treatment decisions (Khatami et al., 2011).

Many studies have been conducted to compare clinical reasoning in dentists having different levels of experience. Most of these studies focussed on the product of the diagnosis and treatment decisions rather than on the process of clinical reasoning which appears to be inconsistent among dentists with different levels of experience, as previously explained (Knutsson et al., 2001, Khatami et al., 2008b, Balto and Al-Madi, 2004).

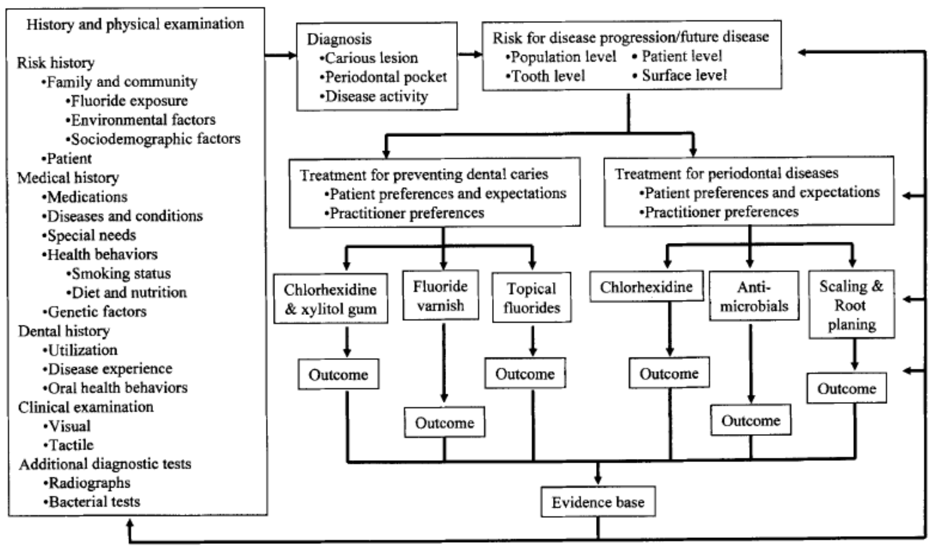

Figure 2:7: Decision model created by White & Maupomé in order to help dentists making clinical decisions by individually analysing the components of the clinical case, Source: (White and Maupomé, 2003)

As the case in other disciplines, researchers have created frameworks to describe clinical reasoning in dentistry. A recent framework is illustrated in Figure 2:8. In 2010, Khatami developed a conceptual framework for clinical reasoning in dentistry. She has described four types of reasoning in dental students, as a result of her qualitative study, as described below:

- Ritual reasoning: this was common among the participating students, who developed and followed a routine and systematic approach of collecting data from patient history, examination and treatment planning which always proceeds through phases of problem management.

- Backward and forward reasoning and a combination of both: some students used backward reasoning in which they propose differential diagnoses and work to either accept or reject them. Other students preferred to collect all the required information and work through to reach an acceptable diagnosis. Some students used a combination of the two techniques to compensate for their limited experience.

- Pattern recognition and scripts: caries scripts, periodontal scripts and orthodontic scripts were commonly used by the students to identify common dental problems.

- Decision analysis: To make a decision and manage a problem the usual process would follow three basic steps of: problem interpretation followed by developing management options and finally evaluating the advantages and disadvantages of the available options. Khatami found that none of the participating students used the Bayesian approach of numerically quantifying the probability or utility value of options. Students have used the interpretive approach of combining their knowledge and experience to tackle the problem and select the appropriate options with acceptable outcomes.

Seven strategies of clinical reasoning in dental students have been also identified by Khatami (2010)*. Scientific reasoning* was a mentioned strategy. It includes the use of an interpretive approach when making a clinical decision. Students depend mainly in their knowledge on theory and experience from textbooks, didactic materials and opinions of instructors and other students. They are also aware of the limitations of this approach in that every case is different.

Another strategy was called *conditional reasoning*. In this approach students consider and analyse all factors contributing to the problem they are dealing with. These include biological, psychological, and socioeconomic factors which contribute to the initiation and progression of the oral problem. Students usually referred to this strategy in analysing the sources of the problem, expecting the other consequent problems the patient may encounter, and the prognosis and outcomes of their intervention.

Collaborative reasoning was also identified. Students usually discuss with the patient the treatment options available and the expected outcomes. This is done to facilitate choosing a desirable and feasible option, to share the responsibilities and to educate the patient to reach an informed decision. Furthermore, consulting with the instructors is necessary in some cases when the student is in doubt about the treatment options or conflicts arise with the patient.

Narrative, *ethical* and *pragmatic reasoning* have been also explained as reasoning strategies in dental students, as discussed earlier in this chapter. *Part-whole reasoning* was mentioned by Khatami (2010) as a reasoning strategy used by dental students. In this strategy, dental students focus on many parts of the dynamic biological system of the mouth including the relationship between teeth and adjacent tissues. A treatment plan designed for a problem related to a specific tooth should be evaluated in relation to other dentition and how teeth are occluded to keep harmony for the dynamic system.

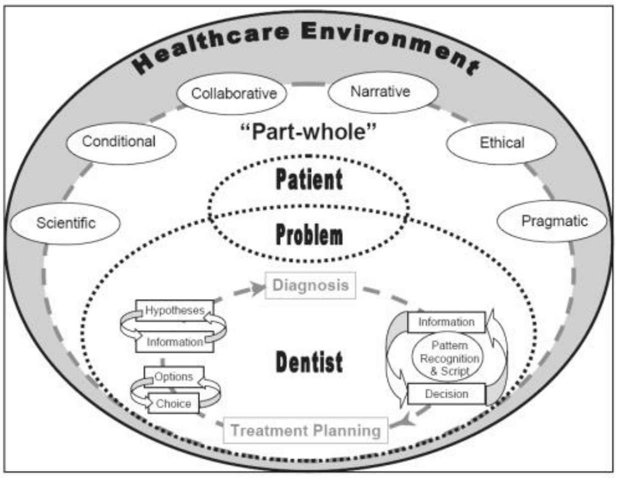

Figure 2:8: A conceptual model of clinical reasoning in dentistry, source: (Khatami et al., 2011).

Gowda and Lamster (2011) have divided clinical reasoning in dentistry into two broad models of theories: *prescriptive* and *descriptive*[3] theories. They argued that a dentist should use both models to overcome the limitations and the possible errors associated with each type. They also suggested and called for procedures to reduce the diagnostic errors.

2.7 Researching clinical reasoning

This chapter discussed clinical reasoning as an important phenomenon in health care professions, focussing on dentistry. It started by getting an overview of this phenomenon and the suggested explanations provided in the literature. It also discussed the acquisition and development of the skills for clinical reasoning. Furthermore, factors which might have an impact on clinical reasoning development were also discussed. Finally, teaching and assessing this skill were explored. The previous section presented the history of clinical reasoning research in

[3] Prescriptive theory refers to rational approaches to diagnostic reasoning e.g. Bayes theorem. Whereas descriptive reasoning refers to intuitive (system 2) approach to make clinical decisions GOWDA, D. & LAMSTER, I. B. 2011. The Diagnostic Process. *Dental Clinics of North America,* 55**,** 1-14.

dentistry. All these discussions were based on a review of the medical and dental literature. However, much of the literature review came from medical literature due to the deficiency of this kind of research in dentistry.

We have identified calls for more research regarding clinical reasoning, as follow:

- Research is needed to identify additional variables that have an impact on clinical reasoning in dentistry.
- Cultural effect on clinical reasoning needs more investigation.
- There is a lack of consensus about clinical reasoning assessment and a call for developing reliable and valid tools that best assess this important skill.
- A call to examine how SCT can integrate with other assessment tools was raised.
- Curriculum effect on the development of clinical reasoning in dental students needs to be investigated, (see Chapter 3).
- A call to study the psychology of decision making in dentistry was also raised.

Now that the nature of clinical reasoning has been outlined, in the following three chapters we aim to discuss the curriculum effects on clinical reasoning development in dental students in two different cultures and different curriculum models. In Chapter 3 we will start by analysing the undergraduate curricula at four different dental schools. We will then discuss our quantitative study in which we compared the results of clinical reasoning by using an innovative Clinical Reasoning Test. This test integrated SCT and other assessment tools for clinical reasoning, (see Chapter 4). Finally, in Chapter 5 we will present our qualitative study. This study aimed to get a deep understanding of clinical reasoning in dentistry. We describe clinical reasoning understanding from the perspectives of students, as this has not been presented in the dental literature. The qualitative study also discusses the differences between the reasoning process of students coming from different curricula and cultures.

3 Chapter 3: Curriculum influences on the development of clinical reasoning skills: the context of the research

Chapter outline

In this chapter, the main models of dental curricula will be described. The impact of the different dental curriculum reforms and models on the development of clinical reasoning will be examined based on reviewing the available dental and medical studies in the literature. Analysis of the undergraduate curricula of the four dental schools involved in this research was made using the SPICES and Integration Ladder as methods. These dental schools were located at: the University of Birmingham, King Abdulaziz University, the University of Manchester and Taibah University. This analysis will be presented in tables to make easy comparison. However, there is no attempt made to evaluate these curricula. Descriptions are provided for the purpose of illustrating the main characteristics of each curriculum model in order to understand the two studies presented in Chapters 4 and 5.

3.1 Introduction

Many factors are thought to have an impact on the development of clinical reasoning skills in medical and dental students. Most of these factors were described in Chapter 2. The results of our quantitative study, to be presented in Chapter 4, showed that the type of undergraduate curriculum had a minimal effect on the marks obtained by the final year students coming from different dental schools using an online clinical reasoning test.

These results agreed with what is argued in the literature about the effect of the different curricula on the development of clinical reasoning skills in medical students. It has been found that although there are significant differences in clinical reasoning ability of medical students from PBL programs compared to students from traditional curricula, this difference diminished when students proceeded to the last years of their study suggesting that towards graduation there is no differences in reasoning ability based on the type of undergraduate curriculum (Da Silva, 2013, Groves et al., 2003a).

On the other hand, the results of our qualitative study, to be presented in Chapter 5, showed that there were some differences in the characteristics of the reasoning *process* used by final year dental students based on their different curriculum models, despite the fact that they might have reached the same conclusions at the end of the reasoning process.

In order to understand the impact of the curricula on clinical reasoning, it is relevant to be aware of the cognitive processes taking place in students' minds as the curriculum structure may influence learning. For example it has been suggested that medical students store knowledge in the same way it has been taught. In a traditional curriculum if pathophysiology for example is taught according to organ systems, then knowledge will be stored and organised in the form of organ systems. Recall of information will be triggered by prompts related to organ systems. This in turn may delay problem solving ability of the students in clinical settings as patients usually present by combinations of symptoms related to multiple organ systems. During the clinical phase students usually form connections between biomedical science and clinical cases making short cuts and faster retrieval of knowledge (Bowen, 2006).

Curriculum characteristics have been argued to affect the decision making process in dentists (Zadik and Levin, 2007). However, there is a lack of research in dentistry on examining the effects of educational strategies on clinical reasoning, for that reason we will frequently mention the relevant medical literature.

It has been reported that dentists greatly rely on their intuition and personal judgement to reason through multiple options in order to achieve the desired outcome for a specific patient. As mentioned in Chapter 2 dentist's judgement and intuition can also make the dentist deviate from the ideal treatment plan or modify it depending on a patient-to-patient basis (Redford and Gift 1997). However, reflection and discussion with dentists from other specialities can influence the initial decision made by a single dentist (Youngson 2011). There is obviously a need to study the impact of the dental curricula on the decision making process in order to formulate effective changes and recommendations for curriculum development. The next section will present the different models of the undergraduate dental curriculum.

3.2 Types of dental curricula

Three well-known models are known as: the traditional, the integrated (with its different levels) and the Problem-Based. Evidence-based and community-based curricula are also considered as useful reforms that could add more value to the dental curriculum.

However, a curriculum model could be hybrid in nature *i.e.* a combination of more than one type of the above mentioned models. Dental curricula could have some degree of integration while still reserving the traditional separation of the preclinical and clinical phases. Some curriculum models may also have a topic or a PBL format running alongside the integrated overall model, and so on. Most dental schools are continuously updating and developing their curricula, and it might be hard to find a contemporary school at which absolute dependence on the purely traditional dental education is implemented.

3.2.1 The traditional dental curriculum

The most common characteristic of the traditional dental curriculum is the separation between the basic and clinical sciences with the former commonly being taught in the first two years by a basic science faculty, which is inconsistently integrated with clinical dental practice. Then, the clinical sciences are usually taught by a dental faculty, who may not be actively involved in research-related activities (Valachovic, 1997, Patel et al., 2004).

In the traditional curriculum students are taught in well-related steps: terminology being the first step followed by states of health, followed by states of disease and finally by clinical care, which is entirely teacher centred (Masella, 2005). Patel *et al* defined a traditional dental curriculum as a format that is based on a clear distinction between the teaching of basic science and the clinical aspects of patient care (Patel et al., 2001). Lectures, group seminars and clinical sessions are features of traditional dental teaching. The reliance on lecturing in the traditional dental curriculum makes it cost effective. According to The Association for Dental Education in Europe (ADEE), this teacher centred approach depends on the hypothetical transmission of knowledge from experienced teachers to students, not necessarily encouraging reflection and learning by students (ADEE, 2010).

Looking at this type of dental curriculum, it has been argued to be excessively dense discipline-based curriculum, crowded with redundant or marginally useful materials. Consequently, it allows insufficient time for students to consolidate concepts or develop critical thinking skills and overloads students with knowledge (Bradley and Mattick, 2008, Kassebaum et al., 2004, Hupp, 2006). We believe that the traditional model of dental curriculum, with its dense nature, could add more stress to students and supress the learning process. We also argue that this format depends mainly on the students' ability to make connections and associate biomedical science knowledge to its clinical application without tutor facilitation. This may further add to the stress faced by students. These arguments are made based on the author's own personal experience at a fairly traditional dental curriculum and the results of a previous research (Nafea, 2011).

Some educators consider this format as no longer suitable for current practice. There is a global call for dental curriculum reform to adapt to the challenges of the global economy and technology and the changing health needs of the community, as well as the training needs of healthcare providers focussing on high technical procedures to the determinant of a more humanistic, holistic and evidence-based approach to dental care (Fincham and Shuler, 2001, Kassebaum et al., 2004, Werb and Matear, 2004, Crain, 2008, Wang et al., 2008).

Future dentists should be prepared to have critical thinking, make evidence based decisions, behave empathically, develop interpersonal skills and continuously update their knowledge (von

Bergmann et al., 2007). Hendricson and Cohen (2001) identified eleven dental education reform recommendations that have been consistently advocated over the years. These recommendations are presented as:

1. Redesign the curriculum to incorporate competency-based learning principles and evaluation methods as required by the Commission on Dental Accreditation Standards.
2. Decompress the curriculum by eliminating outdated and peripherally relevant material.
3. Increase educational collaboration between dentistry and the other health professions, featuring more curricular emphasis on the interaction of dental and medical problems.
4. Redirect basic science coursework toward disease pathophysiology taught by problem-based techniques.
5. Expose students to patients and their oral health and systemic medical problems from the first days of the curriculum to the last.
6. Revitalise the science and underlying clinical decision making via evidence-based approaches.
7. Organise group practice teams in the clinical years to promote more continuity in faculty-student relationships and expand peer teaching by students working together in clinical teams.
8. Increase the use of community-based clinics as training sites for students.
9. Include a clinical experience in the final year of the curriculum or in a postgraduate internship year, which replicates the comprehensive care environment of the general dental practitioner.
10. Utilise computer-based and web-based information technology to enrich student learning.
11. Rededicate dental school clinics to serving the oral health needs of the public rather than primarily viewing patients as educational material for students.

One of the strongly recommended changes is the incorporation of problem-based learning (PBL) into dental education (Fincham et al., 1997, Walton et al., 1997, Whipp et al., 2000, Patel et al., 2001, Werb and Matear, 2004, Huang et al., 2007, McCarlie and Orr, 2010). PBL dental curriculum will be discussed in the following section.

3.2.2 Problem-based learning (PBL)

This section discusses the rationale and history of the PBL in dental education as well as the different models of its implementation.

According to Schmidt, as quoted in (Kelly et al., 1997), the three conditions that facilitate learning are:

1. Learning as a restructuring character. Earlier knowledge is used in understanding new information.
2. Retrieval cues reactivate information. The closer the resemblance between the situation in which something is learnt and the situation in which it is to be applied, the better the performance and easier it is in respect of recall and application.
3. Elaboration of knowledge. Information is better understood, processed, and retrieved if students have an opportunity to elaborate on that information. Students can elaborate by answering questions about the matter, by taking notes, by teaching peers what they have already learnt themselves, by summarising, and by formulating criticising hypothesis about a given problem.

Barrows (2000) defined problem-based learning as "*the learning process which results from working towards the understanding of, or resolution of, a problem*". Barrows as a leader in the field of medical PBL education, focuses on the three most important objectives of PBL, which are:

- The question of a rich body of deeply understood knowledge that is integrated from a wide variety of disciplines, structured in ways that will facilitate recall and application to other problems, and enmeshed with the problem-solving required to analyse and solve patient problems.
- The development of effective clinical problem-solving, self-directed learning, and team and interpersonal skills.
- The development of an insatiable curiosity and a desire to continually learn.

Source: (Barrows, 1998)

According to Mullins *et al* (2001), the characteristics of a PBL curriculum can be summarised, as follows:

- The initial learning occurs in small groups where students explore clinically realistic scenarios.
- Learning takes place in a relevant professional context.
- Students are engaged in deep learning, with good integration and knowledge application.
- The assessment system is contextually based, requiring demonstration of understanding and application of knowledge, with self-assessment being an essential component.
- The learning process itself aims to enhance the development of life-long learning skills such as problem solving and self-directed learning.

Students in the PBL curriculum are regularly exposed to dental terms while engaged in case research. The multidisciplinary PBL has argued to be highly successful in building a foundation for students, which enables them to understand complex dental knowledge and basic science (Masella, 2005).

3.2.2.1 History of PBL in dentistry

The PBL in some form, has been a feature of medical education for several decades, but has only recently been introduced into dental schools and only to a limited extent (Fincham and Shuler, 2001, Patel et al., 2005, von Bergmann et al., 2007, Susarla et al., 2003, Kassebaum et al., 2004, Wang et al., 2008, Mullins et al., 2001, Haden et al., 2010).

Recognising the need for curriculum change and in response to changes in community oral health and needs, a few dental schools in Sweden, Australia, USA, Canada, Hong Kong and the UK have introduced a PBL philosophy into their dental curricula either in a hybrid way or across the entire curriculum (Fincham and Shuler, 2001).

Looking at the history of PBL implementation into dental curricula, Malmo University began the practice of PBL in the early 1990s in Sweden when it was reopened with a completely revised dental curriculum based on PBL. This development stands as a significant milestone in dental education.

In 1994, the Harvard School of Dental Medicine was the first school to introduce hybrid PBL methodology across all areas of basic and clinical dental education. The dental school at Adelaide University was the first in Australia (Mullins et al., 2001).

In a survey done in 2004 on fifty-six North American dental schools, twenty percent of their curricula were traditional discipline and lecture-based 66% were largely discipline-based, with a few interdisciplinary courses and only 14%, which represents 8 schools, demonstrated integrated curricula. Finally, only 5%, three dental schools, have implemented a PBL format in all courses (Kassebaum et al., 2004).

The School of Stomatology at Wuhan University (WHUSS) in China has established a modified PBL in just one single discipline, paedodontics, in 2000. After receiving positive feedback about this implementation, a multidisciplinary PBL curriculum at WHUSS was established. However, only 20% of lectures were replaced by PBL as a result of worries about the probable side effects of this innovation in this specific culture (Huang et al., 2007).

3.2.2.2 Models for implementing a PBL dental curriculum

Dental schools have implemented PBL in different modalities ranging from a single PBL-format course or module, to the complete transformation of the entire curriculum, which occurred at the Hong Kong dental school (Wang et al., 2008).

Perhaps most commonly, a PBL dental curriculum has been developed as a ''horizontal hybrid'' essentially preserving the traditional preclinical/clinical structure and limiting the PBL component to the first two or three years. In this format, the vertical integration is lost (Fincham and Shuler, 2001).

In other cases, the PBL could be implemented into a partially hybrid form in which it is implemented to a single course or block. However, this method could be problematic for the students as they are faced with the confusion of drastically contrasted pedagogies, student-centred vs. teacher-centred, within the same time frame. Consequently, it is likely for the students to have greater focus on the traditional (comfortable) pedagogy.

Another modality of PBL implementation is the initial placement of dental students in a PBL medical curriculum, when there is linkage between medical and dental schools *e.g.* Harvard and the University of British Colombia. The process of changing a traditional dental curriculum to PBL cannot be taken lightly (*ibid*).

The introduction of a PBL program into dental education has occurred in different models. As described earlier in the case of Malmo University, PBL was introduced when the university was reopened (Hsu, 2003). This situation allowed the innovators to freely and easily introduce the new curriculum which is unlikely to occur when dealing with a pre-existing traditional curriculum (Fincham and Shuler, 2001).

3.2.3 The integrated dental curriculum

With the increasing amount of emerging scientific information related to bioscience, it would be difficult to fit this huge amount of knowledge within the allocated time for teaching dental students. The integrated dental curriculum could help in combining and relating different disciplines together avoiding the unnecessary redundancy in the already overloaded traditional curriculum.

Integration of a curriculum refers to mixing the teaching and learning activities and avoiding the separation and segmentation of the disciplines. It is simply the process of bringing together basic and clinical science. The aim is to facilitate the learning process for students by relating knowledge to clinical experience, hoping to make knowledge organised in a deep understandable, retrievable and amendable form with lifelong learning characteristics (Bradley and Mattick, 2008).

Integration of the curriculum can be described as *horizontal* or *vertical*. In the horizontal integration, collaboration and explicit connection are made between the different subject areas in a holistic manner. On the other hand, vertical integration presents clinical science and basic science in a combined and related way breaking the boundaries characterising the traditional curriculum when separating the preclinical and clinical phases. Vertical integration allows students to relate basic knowledge with clinical experience as this knowledge is presented in clinical context (*ibid*).

Integration of the undergraduate curriculum is being spread among medical and dental schools worldwide nowadays as a result of acknowledging the advantages of integration (Kingsley et al., 2007, Bradley and Mattick, 2008). These advantages were summarised by Bradley and Mattick (2008), as follows:

- Improved motivation and satisfaction
- Professional socialisation
- Enhanced self-reflection and self-appraisal
- Reinforced and deep learning
- Prepares for life-long learning
- Improved understanding of biological principles, mechanisms & basic concepts
- Heightened relevance of learning

- Facilitates curriculum review
- Promotes co-operation between staff members from different disciplines
- Enhances clinician reflections on the scientific basis of practice
- Enhances basic scientists reflections on clinical applications and research

3.2.4 Other curriculum reforms

In response to the suggestions made concerning the non-suitability of the traditional dental curriculum for contemporary dental care, many dental schools have implemented changes to their curriculum. Rather than changing the whole curriculum model, they have tried to improve clinical and diagnostic decision making skills for their students. One of the suggested reforms is the development of community-based and evidence-based dentistry.

Community-based dental education is a suggested reform that might help in fostering the development of clinical reasoning skills in dental students. In this form a substantial portion of dental clinical education is shifted from being taught in dental school clinics to be mainly conducted in public health settings. This provides more opportunity for the students to be exposed to a wide range of dental conditions.

Dental treatment options depend on many factors including patient-related, dentist-related, resources- and financially-related factors. In this case dentists may support their treatment decisions using evidence justifying their decisions. In *evidence-based dental education* students are taught to critically appraise published evidence in the literature in order to make decision concerning the best treatment options available for their patients.

After reviewing the different formats of dental curriculum, the following section will discuss the medical and dental literature concerning the role of the undergraduate curriculum in fostering the development of students' clinical reasoning skills.

3.3 The impact of the different types of curriculum on clinical reasoning development

Although, multiple studies have been conducted to examine the effect of the curriculum on clinical reasoning, its role in enhancing the development of clinical reasoning skills in medical and dental students is still not well understood (Patel et al., 1989, Patel and et al., 1991, Sefton et al., 2008, Schmidt et al., 1996, Goss et al., 2011). Most of the results were contradictory and there was no consensus on a single best curriculum model to enhance clinical reasoning. However, recommendations were suggested to develop the curriculum in a way that enhances and fosters the development of the skills required for clinical reasoning. These recommendations were presented in the previous chapter.

The effect of the different types of undergraduate curriculum is not well-researched in dentistry. However, some studies presented the differences in the reasoning strategies used by dental students as a result of curriculum reforms. In this section a literature review will be presented in order to summarise the possible association between the type of dental curriculum and the students' reasoning and problem solving abilities.

3.3.1 Comparing the traditional and the PBL curricula

3.3.1.1 Effectiveness in enhancing clinical reasoning

Most of the comparative studies have focussed on comparing the traditional and the PBL curricula. However, conflicting findings have risen in the literature with no absolute answer as to which one of them could better enhance clinical reasoning skills development. It was found that medical students at a PBL curriculum had better diagnostic accuracy than students at a traditional curriculum (Schmidt et al., 1996). Moreover, a study suggested that dental students in a PBL curriculum performed better than students from a traditional curriculum with regards to communication skills with patients, critical thinking and independent learning skills (Thammasitboon et al., 2007). However, Pardamean (2012a) argued that the PBL does not greatly support the development of critical thinking in dental students compared to the traditional curriculum.

The PBL curriculum was also suggested to promote the critical thinking skills of students (Şendağ and Ferhan Odabaşı, 2009). As being one of the factors affecting the level of clinical reasoning development, critical thinking is thought to enhance the problem solving ability of students (Pardamean, 2012a). A recent study has argued that the traditional medical curriculum is inappropriate to prepare students for clinical experience. It was suggested that the biomedical knowledge taught in the preclinical phase may have no effect, or even a negative relationship, on gaining clinical knowledge by the students (Schauber et al., 2013).

Ratzmann *et al* (2013) suggested that PBL could be integrated effectively as a method of learning in traditional dental curriculum to enhance clinical reasoning, but students' motivation is very important for the learning success.

Some variations were suggested to make the PBL curriculum even better in enhancing the development of reasoning skills. Even in the PBL type of undergraduate curriculum, the type of modes used for presenting the clinical cases are suggested to have different effect on the level of critical thinking. The use of digital video cases in face-to-face or virtual PBL curriculum may enhance the development of critical thinking abilities more than written cases in a PBL curriculum (Kamin et al., 2003). The use of role play by the facilitator was also suggested to enhance the problem solving skills of medical students. In this case after reading the main case scenario, the facilitator plays the role of the patient and responds to interviews by students (Menahem and Paget, 1990).

Electronic PBL, where interactive multimedia was used to resemble problems in clinical settings, has been reported to be used in a medical school to supplement the traditional PBL. The use of e-PBL was suggested to promote the independence of medical students in clinical settings. It was also suggested to enhance the development of individual clinical reasoning and problem solving abilities by the students (Kim and Kee, 2013).

In 1992, Norman and Schmidt (1992) reviewed the published studies claiming the effectiveness of PBL over the traditional medical curriculum. They found that despite the support given to the PBL format there was no evidence that the PBL improves the problem solving skills of students. They also found some preliminary evidence that PBL may enhance the transfer of concepts to new problems and the integration of basic science to clinical problems.

Moreover, Goss *et al* (2011) conducted a study to examine the effectiveness of the PBL curriculum on the development of diagnostic reasoning skills in medical students. Their unexpected findings demonstrated that students on a traditional curriculum had higher flexibility in thinking and memory structure, and consequently a higher level of diagnostic reasoning than students on the PBL curriculum. However, the reason for these results could be caused by the characteristics of the special PBL curriculum they have studied. This curriculum model has a research year during which PBL students do research before their first full time clinical year. The authors suggested that this year-long gap could significantly affect the recall of previous clinical experience by the students. Moreover, students in the traditional curriculum involved in the study were exposed to broad-based clinical training, whereas the PBL students sample was trained mostly in a system-based format with narrow range of clinical problems in each block.

In addition to the above mentioned evidence, which did not support the effectiveness of the PBL format to enhance clinical reasoning development, Jolly (2006) has questioned the effectiveness of the PBL curriculum over the traditional type and stressed on the need for more research and providing reliable evidence for this.

It was also concluded that published studies in medical education between 1992 and 1998 revealed no convincing evidence that the PBL enhanced knowledge acquisition or clinical performance by medical students, but there was a small effect of the PBL curriculum in enhancing the level of clinical reasoning and diagnostic ability (Colliver, 2000).

In response to Colliver, Albanese (2000) disagreed with his findings arguing that there is a wide variety of PBL styles in medicine and evaluating these varieties is not an easy process. Furthermore, it is very hard to find an agreed set of outcome criteria which indicate the success of curriculum intervention. Albanese also found that Colliver had reviewed studies with low sample size that produced non-generalizable results. Moreover, shortly after Colliver published his conclusions, Norman and Schmidt (2000) produced a paper that challenges his findings regarding the marginal effect of PBL in fostering knowledge base and clinical performance. They suggested that the best way to advance the field of medical education should be done by using a systematic research programme and testing the effectiveness of educational intervention in realistic settings accompanied by considerations of all possible variables and interactions.

To support the educators who believe in the effectiveness of the traditional curriculum in enhancing the development of clinical reasoning some researchers suggested alterations and development to this type of curriculum. Alterations to the traditional curriculum may also help to enhance the level of clinical reasoning. The use of simulated patients early in the medical course was claimed to help the students to relate the biomedical science to clinical experience as expressed by the students (Thomas, 1992).

The traditional curriculum can also foster the development of problem solving skills in medical students when it is augmented by the use of aspects of the PBL and small group learning. In this case students showed increased use of data driven reasoning and better integration between biomedical science and clinical reasoning (Patel et al., 2005). It has been suggested that small group teaching provides more opportunities for discussion and greater integration of knowledge to clinical context than lectures (*ibid*).

3.3.1.2 Students’ perception

The researchers’ debate regarding the effectiveness of the traditional and the PBL curricula was also reflected in the students’ point of view. Medical students in a traditional curriculum reported themselves more ready and well prepared to practice clinical work during the internship period than students in a PBL curriculum who reported difficulties in acquiring skills for clinical reasoning (Millan et al., 2012). However, when a PBL was complemented by Team-based learning, which involved repeated tests, clinical reasoning ability was enhanced in students with PBL experience

(Okubo et al., 2012). Students in a PBL model thought that it improved their ability to produce a treatment plan and understand the importance of communicating with their patients (Norose, 2013). Furthermore, in another study dental students reported that a PBL curriculum helped them to get deeper understanding of multiple dental topics and also facilitated their link and usage of the basic science knowledge to clinical cases (Barman et al., 2006).

3.3.1.3 Comparing the process of clinical reasoning

Other comparative studies have focussed on the reasoning process *per se* and the knowledge organisation to show the difference between the traditional and the PBL models. We will now discuss these studies.

Barrow and Pickell (1991) argued that the PBL medical curriculum supports and directs students to use hypothetico-deductive reasoning through the interactive process of hypothesis generation, testing, refinement and synthesis. Dental students in a traditional curriculum tend to be more inclined to use hypothesis driven approaches to decision making rather than the data driven approach characterised by the PBL students (Patel et al., 2005). Pardamean (2012a) has argued that because students in the traditional dental curriculum are taught in a way that focuses on dental diseases and their different forms, signs and symptoms *etc.* before they start to see real patients, they tend to develop specific reasoning strategies. They are usually inclined to review all the possible diseases and the differential diagnoses associating them to their signs and symptoms in a way that include or exclude possible dental conditions when they are dealing with real patients rather than being driven by the features this specific patient may have. However, in a PBL dental curriculum students are presented with dental cases early in their undergraduate course. Students in this case are directed to collect all the relevant information from the patient's history and presentation and work through the case to reach the final diagnosis. It was found that the PBL curriculum may facilitate the development of inductive reasoning in students.

The same results have also been obtained for medical students as well (Patel et al., 2005). However, the PBL students committed errors of scientific fact and generated less coherent explanations than students on a conventional medical curriculum (Patel et al., 1993).

Moreover, Kaufman *et al* (2008) explained the clinical reasoning characteristics of students on a PBL curriculum as being of a deductive nature. These students have a strong ability to apply the biomedical information to clinical context. However, this strong association and integration between basic science and clinical knowledge result in students' inability to decontextualize the clinical problem they are dealing with. Even if the clinical condition demands that students separate between the basic science and the clinical context, they cannot easily detach the two. Students tend to provide greater number elaborations when they think about problem features using basic science and clinical information. Consequently, this greater elaboration leads to fragmentation of knowledge structures. As a result, there is lack of global coherence, as various parts of the problem are not connected, resulting in diagnostic errors. The authors also concluded that some aspects of medicine are best taught in context while others require formal teaching.

As discussed earlier, in Chapter 2, it has been suggested that medical students reasoning is influenced by the way they are taught and knowledge is stored in the same way it is delivered to them. For example, in the PBL curriculum students are taught to apply basic biomedical science knowledge in the context of clinical problems. In contrast, the characteristic separation between the preclinical and clinical phases in the traditional curriculum might render students unable to associate links between the abstractly taught biomedical and clinical knowledge. As a result, biomedical knowledge could be difficult to integrate into clinical practice (Norman and Schmidt, 2000).

The main concept of traditional medical and dental curricula is to provide an extensive base of biomedical knowledge in the preclinical phase of the undergraduate study. This basic knowledge is thought to be broadly applicable to the clinical cases that the students engage with during the clinical phase of their course. However, the PBL system is different in that students are taught to apply biomedical knowledge to clinical cases from the start of their study. It has been suggested that students would be more able to relate this knowledge to clinical practice and hence increased their clinical reasoning abilities.

In real dental practice a dentist does not retrieve basic biomedical knowledge taught in an extensive way during the preclinical phase. Instead, he/she develops shortcuts (scripts) to the clinical cases usually seen in practice. As an example, a patient with dry mouth may come to dental practice seeking for a solution to his problem. The dentist/dental student in this case does not need to use the knowledge of salivary glands anatomy, instead the clinical knowledge of the signs and symptoms associated with some medical conditions are required in this case. The student may request tests for diabetes for example, and the process will continue towards finding the proper diagnosis and management options.

3.3.2 The effectiveness of the integrated curriculum

Little attention has been paid to comparing the integrated type and other types of curriculum in contrast to the extensive comparison between the traditional and the PBL curricula in the medical literature. One of the comparative studies which involved comparing the diagnostic accuracy of medical students from the three different types of curriculum revealed that students from the integrated and the PBL curricula performed better than students from a traditional type of curriculum. Another finding of the same study also revealed a difference in the marks obtained for second and third year students, being higher for students from the integrated curriculum than that which were obtained for the other two types of medical curricula (Schmidt et al., 1996).

The process of knowledge encapsulation, (discussed in Chapter 2), is suggested to be enhanced by integrating biomedical and clinical knowledge in an integrated type of medical curriculum. This in turn increases the development of expertise and clinical reasoning skills (Boshuizen and Schmidt, 1990). Furthermore, in the integrated curriculum both biomedical and clinical knowledge are taught in an integrated way, which helps them to associate and merge into a coherent knowledge structure. Consequently, this knowledge structure provides a strong base of knowledge for students to be used in clinical settings and hence enhance the development of clinical reasoning skills in medical students (Kaufman et al., 2008).

3.3.3 The effectiveness of evidence-based and community-based education

We will now discuss the available literature regarding the effectiveness of the evidence-based and the community-based dental curricula in fostering the development of clinical reasoning skills. The use of evidence-based dentistry is suggested to improve dentists’ decision making skills (Faggion and Tu, 2007). It has also been suggested to be used in order to improve decision making by the dentists and overcome misconceptions caused by dentists’ reliance on their personal experience or opinions, it is also thought to improve patients care (Rinchuse et al., 2005).

However, Monaghan (1999) concluded that even if the evidence-based approach is widely used people will still make biased decisions which are parts of the human nature that cannot be overcome. Traditionally, there were considerable resistance to rely on published evidence when making clinical decision in dentistry. The concerns were about restriction of the freedom in decision making and the human nature to resist changes. The critique against the use of evidence-based dentistry depends on the fact that researchers were biased and inconsistent when conducting research, as stated by Monaghan.

It has been suggested that students in a community-based dental curriculum would be exposed to the community and practice treatment for the common dental disorders found in their specific culture. They can also benefit from working in groups and practice their communication skills with the patients and other group members. By developing their communication skills, students are expected to develop their reasoning skills (Strauss et al., 2010). The effect of communication skills and clinical reasoning was discussed in Chapter 2.

In addition, it has been suggested that considerable improvement of dental education can be attained by fostering the development of communication skills and understanding patients’ perceptions by providing dental students with community based training very early in their undergraduate course (Ratzmann et al., 2007). The early introduction of dental students to the clinical environment has been shown to enhance contextual learning and high level of integration of the biomedical and clinical knowledge (Gerzina et al., 2005), which in turn improves the development of clinical reasoning.

The sociocultural element of dental conditions is considered as an important factor affecting the decision making process (Khatami, 2010, Strauss et al., 2010). We argue that practicing in a community-based clinic might expose dental students to this important element. By practicing in context, the students can learn better and develop the skills necessary for clinical reasoning according to situativity theory described in Chapter 2.

3.4 The context of the research

In the previous sections the common models and reforms of the dental curriculum were discussed. Moreover, the impact of these different models on the development of clinical reasoning was also discussed based on the available medical and dental literature.

The following two chapters will present studies of the influence of the type of undergraduate curriculum on the clinical reasoning skills in dental students. The student samples used in the two studies, (see Chapter 4 & 5), were chosen from four dental schools at, the Universities of Birmingham, King Abdulaziz, Manchester and Taibah. In order to understand the effect of curriculum on the development of clinical reasoning, some features of the four curriculum models at these schools will be described and presented against each other in the following section. The methods used for this description were the SPICES model and the Integration Ladder, to be described later.

Curriculum comparative studies might be used for assessing the curriculum for its effectiveness. This is a common practice, which can be examined through the assessment of students' performance. Many medical schools have joined and applied collaborative assessment for their undergraduate students *e.g.* The Universities Medical Assessment Partnership (UMAP) (2012); which is a collaborative project which has 14 partners of the UK medical schools. There are also some international attempts to enhance the collaboration of medical students' assessment such as The International Database for Enhanced Assessment and Learning (IDEAL). The consortium for IDEAL was formally established at a meeting in Hong Kong in December 2001. This is an international consortium intends to develop and maintain a bank of high quality test items (Prideaux and Gordon, 2002). In addition to its multiple advantages of enhancing the assessment of medical students, raising the standards of written assessment, cost-effectiveness and item sharing its main value is the opportunities it creates to compare the effectiveness of different curricula and discover the problematic areas in certain schools (Muijtjens et al., 2008).

There are a few studies conducted in the literature to compare different dental curricula. Most of the comparative studies were conducted to examine the effectiveness of new undergraduate programs compared to the traditional ones (Komabayashi et al., 2012). Some of these studies have compared curricula of different dental schools in different countries *e.g.* China and Japan. In their study Sun *et al* (2012) used search engines with search references and survey as methodology for the comparison followed by a statistical analysis.

The idea of benchmarking could be seen as a straightforward process. However, to carry out an effective curricula comparison, hidden components of the involved curricula should be also considered. These include and not limited to students' effect, admission strategies and teacher experience of benchmarking

(Schmidt, 1990). For that reason a single benchmarking could not be fair to compare different curricula especially in different cultural settings.

Giroux (2001) defines the hidden curriculum as "*those unstated norms, values, and beliefs embedded in and transmitted to students through the underlying rules that structure the routines and social relationships in school and classroom*". It is also defined by Margolis (2001) as curriculum, or unintentional learning (as he described it) that describes the beliefs, values, aims, outcomes and practices that are not clearly stated as being part of the curriculum but are conveyed in it.

In the following discussion getting involved in describing the hidden, unwritten, curriculum effects on the development of clinical reasoning skills will be intentionally avoided. The following comparison only provides analysis to illustrate the main differences between these curricula in order to understand the context of our quantitative and qualitative studies described in Chapters 4 and 5.

This decision was made because of the wide area of research required to explain the complex theories of hidden curriculum resulting from the interaction of various factors such as environment, culture, and the unexpected, unintentional interactions between teachers and students (Kentli, 2009). Furthermore, to explain the effect of hidden curriculum on the development of clinical reasoning skills a high level of analysis of the educational practice is required for each school. Carrying out this detailed analysis would take time and effort which were beyond the scope of this research.

3.4.1 The dental schools involved in the research

The following section will provide an overview of the dental education systems in the UK and Saudi Arabia. It will also discuss general information about the four dental schools involved in the research.

3.4.1.1 Description of dental education in the UK and Saudi Arabia

The information discussed in this section was mainly obtained by using internet search engine for keywords: dental education, dental school, UK, Saudi Arabia, curriculum. Information about the specific curricula was also obtained from personal communication with course administrators and staff in these schools (Seymour, 2014, Agou, 2014, White, 2014, Hifnawy, 2014).

3.4.1.1.1 Dental education in the UK

There are eighteen UK dental schools. It was found that the UK Dental School Council and the General Dental Council provide useful information about undergraduate dental education in the UK (Dental Schools Council, 2008, General Dental Council, 2014). In general, it requires an undergraduate to study for five years in order to be qualified for The Bachelor of Dental Surgery (BDS) degree. Pathways are either graduate entry or a standard one for school leavers. Entry requirements depend on the school itself. There are guiding principles for the admission of dental students, which all the UK dental schools agreed upon. Some dental schools also use The UK Aptitude Test (UKCAT) for their students' selection process (UKCAT Consortium, 2014). After qualification, graduates are expected, but not required, to attend one or two years of vocational training (General Professional Training).

The governing body for quality assurance, the General Dental Council (GDC), regulates dentists and dental care professionals in the UK. GDC sets general standards for dental education programmes to be accepted. These are as follows:

1. Patient protection
2. Quality evaluation and review
3. Student assessment
4. Equality and diversity

3.4.1.1.2 Dental education in Saudi Arabia

Up to the moment, there are 24 public and 8 private universities in Saudi Arabia of which nineteen governmental and six private have dental schools (Information Office of the Royal Embassy of Saudi Arabia in Washington, 2013, Umm Al-Qura University, 2014). All dental collages are regulated by the Ministry of Higher Education (MOHE), first established in 1975. However, these schools got a high level of independency in both administrative and academic scopes (MOHE, 2014a).

Admission to universities is based on both high school grades and a General Aptitude Test (*Qudrat test)*. This test had gained acceptance amongst higher education institutions in the Arabian Gulf region and in some countries including United Kingdom and the United States.

National Commission for Academic Accreditation & Assessment (NCAAA) is a governmental sector responsible to assess and accredit all post-secondary education institutions and programs in the kingdom. It sets criteria for in-site assessment, alignment with national framework for qualifications, and complying with quality measures in aspects of programs, student management, institution management and faculty management (MOHE, 2014b). NCAAA (2010) sets standards and also provides guidelines for institutions to do their internal assessment and to be prepared for external review.

Below is a description of the BDS program at the four different dental schools of interest in the current research, their admission criteria and objectives as presented in their websites and/or curriculum documentation.

3.4.1.2 The Dental School at the University of Birmingham

As presented in the school website the selection process for admission to this school depends on academic excellence, motivation, commitment, involvement and understanding of the need to be working for the benefit of others in the wider community and an understanding of the need for empathy when dealing with other members. Then strong applicants are interviewed to be offered a place to study.

In general the BDS program like all the UK dental schools consists of a total of five years. The first five terms of the program focus on pre-clinical studies followed by three years and a term of clinical work in the Birmingham Dental Hospital. Teaching and learning is described as 'a range of learning and teaching methods throughout the course, including lectures, small group work and individual tuition in clinical areas. The emphasis throughout is on giving students constructive feedback, an insight into their own learning style and ongoing information about how they are progressing in academic and clinical studies. This dental school has an in-house virtual learning environment (the e-course), which provides complementary learning materials and supports students in their enquiry-based approach to learning (University of Birmingham, 2014).

3.4.1.3 The Dental School at the University of Manchester

The BDS programme consists of either a five-year or six-year course with a foundation year. The entry requirements and the selection criteria include UCAS form supplied by the applicants, which should reflect enthusiasm towards dentistry and the reason for choosing dentistry. Applicant must undertake a minimum of two weeks work experience in a general dental practice. Future students should also refer to some team work activities they carried out. This is important because the PBL used in this course relies on team work. They also need to convince the school about their manual dexterity abilities. Applicants should pass the aptitude test (UKCAT), described earlier and other general requirements.

In general, the course includes Enquiry-based learning, small group teaching and early clinical experience together with PBL. It follows the student-centred approach to learning. The course aims to develop professional and ethical dentists who can:

•Take a patient-centred approach to clinical care within the dental team

•Apply the skills, knowledge, behaviours and abilities to practise safely and efficiently

•Be a reflective practitioner committed to lifelong learning

Special features of the course include: enquiry-based learning, small group teaching, outreach community clinics, emphasis on research, early clinical experience, opportunities for interdisciplinary learning between students of dentistry and student professionals complementary to dentistry *e.g.* student dental hygienist/therapists/technicians and opportunity to undertake an intercalated BSc.

A key feature is the integration between theory and practice, and early learning and teaching in the clinical context is central to this.

Clinical subjects are taught alongside the basic dental science subjects. The course is designed around five themes: human health and disease; the mouth in health and disease; clinical competence (including diagnostic skills, manual skills and dexterity, problem solving and patient management); scientific understanding and thought; and skills as team working, communication skills, ICT and reflective practice.

After successful completion of their five-year study, students are qualified for BDS certificate. Students may apply for one year of vocational training after their qualification, yet this is not compulsory (School of Dentistry at the University of Manchester, 2013)

3.4.1.4 The Dental School at King Abdulaziz University

This dental school is the second oldest dental school in Saudi Arabia. The faculty of dentistry at King Abdluaziz University (KAUFD) is the pioneer and the only dental school in the Middle East that strive international quality assurance mechanism via its association with the Association of Dental Education in Europe (ADEE).The Faculty of Dentistry is organized into four departments and 14 divisions. The basic medical science courses are provided by the Faculty of Medicine. The Faculty of Dentistry and its departments provide quality dental education as well as excellent clinical services to the public by fully utilizing the facilities at their disposal in the new Dental Education Centre and clinics.

In general, it takes the undergraduate student six years and one compulsory year of internship to be qualified for BDS. The first year, preparation year, focuses mainly on comprehensive basic science courses such as statistics, chemistry and biology in addition to intensive English language courses to prepare students for the following years which are completely taught in English as well as computer sciences. There is also a course of communication skills.

During the second year, students take general medicine basic sciences subjects such as gross anatomy, physiology and histology and embryology in addition to six hour a week of dental anatomy and occlusion. During the third year, subjects of general medicine such as pharmacology, microbiology, immunology and parasitology are still taught by members from the medical school. However, there is more focus on dental subjects like oral pathology, oral histology, preclinical operative dentistry, oral radiology and biomaterials.

The fourth year of the undergraduate study still has some general medicine subjects such as general surgery, ENT and general anaesthesia, but more dental subjects are added to the schedule. These include, but not limited to oral diagnosis and treatment planning, periodontics, oral biology and nutrition. Other subjects such as professional ethics and law and practice management are also added**.** This year represents the start of the clinical years during which students deal with real patients.

The Fifth year however is completely concerned with dental subjects in addition to pharmacology. The final year is purely dental in nature with more focus on comprehensive care clinic.

The internship year is compulsory and students should fulfil all the requirements of their training year in order to graduate. Evaluation certificate for the internship year is attached to the PDS certificate.

Admission criteria are set by faculty council and agreed by the university council. Applicants should fulfil general requirements of passing the general secondary school certificate, be of a good construct and behaviour in addition to passing the examinations and the interview held by the faculty council.

Academic Assessment Unit in the Faculty of Dentistry has been originated according to college dean decree dated on 2004 as an academic unit that is directly linked to the Dean and is concerned with academic assessment of all departments and branches of the College of Dentistry (self-evaluation). In addition, this unit is responsible for achieving national as well as international accreditation.

3.4.1.5 The Dental School at Taibah University

Dental collage at Taibah University was established in 2007. The collage is located in Madinah, a Holy city in the north area of Saudi Arabia. Undergraduate students should pass the preparatory year in order to be able to continue their study. After passing the preparatory years they can go to the first year of their dental studies which last for five years. Successful pass of a total of six years and a compulsory year of internship training are required to be qualified for BDS.

Objectives of the BDS course include: implementing the highest standards in education and training using the up to date tools, upgrading the level of dental graduates according to market needs in modern aspects of dental sciences through symposia, workshops and continuous medical education, and implementing international standards for academic accreditation for the academic degrees offered by the college.

Admission requires successful pass of both general skills test and a comprehensive aptitude test. This is in addition to other general requirements. Then, applicants are allocated for interviews.

The course is composed of preclinical and clinical subjects, elective courses and research project, in addition to general subjects required by the university. Teaching includes lecture, clinical and laboratory sessions. The first and second years are known as a pre-clinical phase. During the first year students are taught the following subjects: introduction to dental education, anatomy, histology and embryology, physiology, biochemistry, bio-dental Materials, dental public health and dental anatomy.

The second year program consists of general medicine subjects with more focus on dental subjects such as removable dentistry, dental pharmacology and oral radiology. It also has an integrated course of dentistry. Third year offers more dental subjects covering most of the dental disciplines such as periodontics, oral pathology and fixed prosthodontic in addition to general medicine subjects. There is an elective course and an integrated course offered for students during this year. Students also start their clinical work in their third year.

The fourth year is quiet similar to the third year, but covers more advanced levels of dental subjects. Comprehensive care clinic and a research project are added to the fifth year program. Finally, students are evaluated also for their internship work by dental clinical supervisors in order to get their BDS qualification.

3.4.2 Materials and methods: frameworks used to describe the different models of curriculum

In the following section materials and methods used in this comparative study will be described. These are the SPICES and the Integration Ladder frameworks, which comprise well-known measurement for curriculum evaluation. We intentionally avoided comparing the hidden and informal[4] curricula as such analysis

[4] Informal curriculum refers to 'an unscripted, predominantly ad hoc, and highly interpersonal form of teaching and learning that takes place among and between faculty and students' HAFFERTY, F. W. 1998. Beyond curriculum reform: confronting medicine's hidden curriculum. *Acad Med,* 73**,** 403-407.

would require extensive data collection and would be beyond the scope of the current research.

3.4.2.1 The SPICES model of medical and dental curriculum

As stated by Lawrence (2008), all medical colleges can locate themselves somewhere along the continua created by Harden *et al*. We suggest that the SPICES model is also applicable to any dental curriculum.

Harden *et al* identified six educational strategies and represented them in a continuum or a spectrum. The strategy components of the SPICES model are: **S**tudent-centred/teacher-centred, **P**roblem-based/information gathering, **I**ntegrated/discipline-based, **C**ommunity-based/hospital-based, **E**lective/uniform and **S**ystematic/apprenticeship-based (Harden et al., 1984).

S	student centred	*vs*	teacher centred	**T**
P	problem based	*vs*	information gathering	**I**
I	integrated	*vs*	discipline based	**D**
C	community based	*vs*	hospital based	**H**
E	elective	*vs*	uniformed/standard	**U**
S	systematic	*vs*	apprenticeship	**A**

3.4.2.2 The Integration Ladder

The other tool used in this project to compare the different curricula of the dental schools participating in this project is the Integration Ladder. This tool was developed by Harden in 2000 (Harden, 2000). Harden sets eleven points on a continuum as regards to the level of integration of a medical curriculum, namely: Isolation, Awareness, Harmonisation, Nesting, Temporal co-ordination, Sharing, Correlation, Complementary, Multi-disciplinary, Inter-disciplinary and Trans-disciplinary.

Integration was a component in the SPICES model with full integration at one extreme and discipline-based teaching at the other. In the current study we intend to involve the level of integration following the Integrated Ladder framework in the '*I*' component of the SPICES model for each dental school.

Harden described eleven intermediate points between the two extremes. The first four steps of the ladder represent subject or discipline-based curricula in varying degrees. The following six steps stress on integration among several disciplines. The uppermost step represents a case where the student is being more responsible for integration with the guidance provided. The integration ladder as described by Harden (2000) can be summarised, as follows:

- **Isolation** is the first step in the integration ladder. In this case the curriculum is designed in a way to be discipline-based. Each department or subject is seen as a separate entity. Subject specialists are responsible to organise their teaching in isolation to other subjects or discipline, which can be related to their discipline or subject. Students are assessed in a subject-based manner with the consideration to cover the objectives of that discipline. Timetable is set to have lectures of different subjects without being bothered by or being aware of what is taught in another subject. This usually happens in the traditional curriculum.

- The second step is **Awareness**. In this case teaching is still in subject-based form. However, teacher of one subject is aware of what is taught in another subject. Teachers and students are informed of the situation avoiding the unnecessary repetition and redundancy. Despite the awareness, there is no explicit attempt to help students to consider the integrated view of the subject.

- **Harmonisation**, connection or consultation is the next step in the ladder. In this model of the curriculum teachers of the different subjects or different courses of the same subjects communicate with each other, during informal discussion or formal meetings, to relate and adapt their teaching to be connected contributing to the overall objectives of the curriculum. Teaching is still discipline-based, but there is explicit effort to relate curricula with the discipline.

- The fourth step is **Nesting** or infusion. In this step, the curriculum is still in the form of subject-based. However, teachers of one subject target skills related to other subjects. Teacher analyses the goals of other subjects and refines and infuses theses skills into his/her teaching of the specific subject.

- **Temporal co-ordination**, also known as parallel teaching or concurrent teaching is the next step in the integration ladder. This is also a level of integration in a subject-based curriculum, in which the time table is set to cover similar topics in different subjects at the same time, during the same day or in the same week. Students are left to relate and connect the contents of similar topics themselves. An example is when a course of the anatomy of facial muscles is scheduled parallel to pathology of facial muscles.

- The sixth step is known as **Sharing**, or joint teaching. In this case two separate departments plan to teach and deliver a shared programme more effectively than if they teach it separately. They share concepts, skills and attitude.

- Step seven is **Correlation**, which is also known as concomitant or democratic programme. Although, most of the curriculum time is been occupied by subject-base teaching, in this step of integration there is an integrated teaching session or course. In this course common areas of interest are combined from the different subjects. It could also be in a form of assessment in which students are asked to produce an assignment integrating different subjects.

- The eighth step in the integration ladder is **Complementary programme**, or mixed programme. In this level of curriculum integration the approach implement integrated sessions in which discipline contribute to teaching. The main feature of the curriculum is the integrated courses, but there is still an opportunity for discipline-based teaching.

- **Multi-disciplinary** (webbed, contributory) is the following step in the ladder. In this case the curriculum is characterised by

Implementation of a single integrated course with a number of subject areas by a multidisciplinary approach. This course is dealt with as having themes, problems, topics or issues constituting the focus of students’ learning.

- The tenth step is **Inter-disciplinary**, or monolithic. Here the focus of this approach is on themes and on the commonalities and contributions of the subjects to themes. This can be described as an interdisciplinary approach with a high level of integration in which contents of all or most discipline contribute to a new course with no identification to the contributing disciplines in the time table.

- Finally, the highest level of integration is indicated as **Trans-disciplinary**. It can be also described as fusion, immersion, or authentic. In this step the curriculum is described as being similar to interdisciplinary, but the focus is on the field of knowledge rather than themes. This knowledge is arranged to resemble the real world.

3.4.3 Results: juxtaposition tables

The results of the current comparative study are presented in the form of tables. Juxtaposition tables were created in order to make the comparison between the four dental schools easier. In each of the following tables the SPICES components were described and the level of integration according to the Integration Ladder was discussed in the integration component of the SCPICES model.

3.4.3.1 Student-centred/teacher-centred

Table 3:1 summarises the extremes related to the first component of the SPICES model. Table 3:2 allocates each school in relation to its position in the spectrum.

Table 3:1: Summary of the differences between the student-centred and teacher-centred approaches, adapted from (Mehay, n.d.).

Student centred	Teacher centred
SUMMARY	SUMMARY
Learners involved in curriculum design	Teachers design the curriculum
Teaching content based on learners' agenda	Teaching content prescribed by teachers on basis of what they feel learners should know
Leaner centre methods used *e.g.* small group work	Largely dictatorial *e.g.* lectures
Expert outside speakers/resources little used	Expert resources often used (and often deliver on their own agenda!)
Encourages self-directed learning	Encourages a sit and listen approach
Requires hard work to organise (and can be expensive)	Easy to organise (and cheap)
Facilitators may need instruction and training	Most lecturers are used to this model

Table 3:2: Position of the four dental schools regarding the student-centred vs teacher-centred component of the SPICES model

Birmingham	Manchester	King Abdulaziz	Taibah
Different teaching methods are used, including lectures, small group work and individual tuition in clinical areas, with the emphasis on enquiry-based learning. Students are expected to become independent and self-motivated with the support of a virtual learning environment, the e-course. Students also contribute to setting of the curriculum objectives indirectly by reporting their needs and feedback in a special e-course.	Student centred approach is used. The course is designed by the students and staff of the School of Dentistry to provide an integrated, enquiry-based learning and teaching including problem-based learning (PBL).	The course is described as a competency-based education, with the focus on teaching and training the students to reach a certain high level of competency. Terms like *to educate and train, providing educational experience* are common in the course objectives description. This is together with the emphasis on lectures and practical supervision training indicating a teacher-centred approach. However, students are strongly encouraged to carry out research and participate in conferences.	Various ways of assimilating dental and oral information through lectures, group discussions, and assignments are used in teaching. It enables students to employ self-directed learning methods. Students should submit research project in their fifth year.

3.4.3.2 Problem-based vs information gathering

Table 3:3 describes the second component of the SPICES model. Table 3:4 highlights the differences between the dental schools in relation to this component.

Table 3:3: Summary of the main differences between problem-based and information gathering component of the SPICES model, adapted from (Mehay, n.d.).

Problem based	Information gathering
SUMMARY Rids the irrelevance of the mounds of knowledge which learners have to acquire involve patient problem scenarios, health care delivery problems and ethical issues development of an integrated body of knowledge that is deeper, more effective, and has greater content relevance in the appropriate context Core messages of a discipline might be missed with this approach	SUMMARY Rids the irrelevance of the mounds of knowledge which learners have to acquire Superficial knowledge which soon becomes out of date Enables each discipline to convey its core messages

Table 3:4: Position of each dental school in relation to the second component of the SPICES model

Birmingham	Manchester	King Abdulaziz	Taibah
Mixture of problem-based and information gathering. The common feature of the curriculum is enquiry-based system. Biomedical sciences are being taught by tutors from the faculty of medicine and follow a system based teaching approach. Students are also encouraged to think	Problem-based learning is used. The course is designed to have five themes. 1.Human Health and Disease 2.The Mouth in Health and Disease 3.Clinical Competence: •Diagnostic Skills •Manual Skills and Dexterity •Problem Solving	Manly discipline-based teaching in which experts from each discipline teach subjects related to that particular discipline. By analysing the curriculum documents, it was found that each discipline sets goals and objectives that are specific to it. Assessment is also specific for each discipline. However, during the final year	The curriculum used is a mixture of information gathering and some courses that incorporate multi-disciplinary problems using problem-based learning approach, *e.g.* integrated dentistry and ethics of dental practice. Discipline based teaching is the common feature of the curriculum. Subjects such as physiology, anatomy and pharmacology are taught by tutors from the medical college. Each discipline is able to

and integrate knowledge. This is together with lectures delivered by tutors from different disciplines.	•Patient Management 4.Scientific Understanding and Thought 5.Team working, Communication Skills, ICT, reflective practice	students are required to provide and present comprehensive dental treatment to their patients and are assessed by faculties from multiple disciplines.	convey its core messages, aims and objective regarding the cognitive, psychomotor and affective domains.

3.4.3.3 Integrated vs Discipline based

Table 3:5 illustrates the two extremes related to the third component of the SPICES model. The level of curriculum integration is presented in Table 3:6 following the Integration Ladder model.

Table 3:5: Summary of the main differences between integrated and discipline-based components of the SPICES model, adapted from (Mehay, n.d.)

Integrated	Discipline based
SUMMARY Integration between the various disciplines *i.e.* how they relate to each other	SUMMARY Learners have to figure out the integration bit themselves key concepts of a discipline are conveyed which may otherwise be lost in an integrated approach

Table 3:6: Position of each dental school in relation to the third component of the SPICES model and the level of integration in each curriculum according to the Integration Ladder model

Birmingham	Manchester	King Abdulaziz	Taibah
The level of integration is between correlation and complementary programme. Curriculum includes strands modules that continue through different years of the undergraduate study in addition to big integrated modules during the clinical years. This is besides the discipline-based teaching.	Inter-disciplinary integration. The course focuses on five themes: 1.Human Health and Disease 2.The Mouth in Health and Disease 3.Clinical Competence: •Diagnostic Skills •Manual Skills and Dexterity •Problem Solving •Patient Management 4.Scientific Understanding and Thought 5.Team working, Communication Skills, ICT, reflective practice	Isolation is the framework used. Teaching is discipline-based. Experts in each field teach students with the aim to cover all the information required for that specific field and achieving its objectives regardless of other disciplines. Although the comprehensive care clinics training in the final year is a mixture of disciplines, this training is used mainly for the purpose of assessing the competency levels of students.	Correlation framework. During the second, third and fourth year, there is a specific course, *Integrated Dentistry*. The aim of this course is to enable the students to utilize abilities and skills acquired during the 1st and 2nd years in an integrated manner. This course is designed to enable dental students to understand the basic dental sciences through problem based learning. This is besides the discipline-based teaching constitutes a correlation level of curriculum integration.

3.4.3.4 Community based Vs hospital based

The fourth component of the SPICES model is described in Table 3:7, and the associated differences between the dental schools are presented in Table 3:8.

Table 3:7: Summary of the main differences between the community-based and hospital-based education, adapted from (Mehay, n.d.)

Community based	Hospital based
SUMMARY Direct contact with the community the learners are being taught to serve See a wide variety of conditions at a wide variety of stages Learners learn about the social and economic aspect of illness Learners see patients in their own homes	SUMMARY See only a small subsection of the community See specialised diseases usually in extremis Social and economic aspects of illness often ignored No consideration of the patients environment Can provide focused instruction in specialised areas

Table 3:8: Position of each dental school regarding the community-based vs hospital-based component of the SPICES model

Birmingham	Manchester	King Abdulaziz	Taibah
A combination of hospital and community-based placement. As stated in the website: pre-clinical studies are followed by three years and a term of clinical work in the Birmingham Dental Hospital. Outreach placements for adult and children primary dental care takes place in community clinics	Community-based training is taken place. As a requirement for admission, students should provide a proof of work experience of a minimum of two weeks in a general dental practice. Then students are trained in outreach community clinics.	A combination of hospital and community-based placement. Community dentistry is being taught and one of its requirements is to visit patients in their own environment.	A combination of hospital and community-based placement. Students do their clinical courses throughout the third, fourth and fifth years. Community dentistry is a course with the aiming to enable the students to understand the principles of public dental health practice with emphasis on dental epidemiology and preventive dentistry at the community level. In addition, students learn the Rural Health Education Partnerships Program

3.4.3.5 Elective vs uniform

Table 3:9 presents the difference between elective and uniform curriculum model. The differences between the four dental schools with regards to the fourth component of the SPICES model are presented in Table 3:10.

Table 3:9: Summary of the fifth component of the SPICES model, adapted from (Mehay, n.d.)

Elective	Uniform
SUMMARY Allows curricular flexibility Enables learners to explore further interests in more details; matching to the learner's needs Can see health delivery in a state elsewhere (secondments) Promotes self-directed learning	SUMMARY Standard programme through which all must go through No such opportunity. But does provide "core" experience which is prescribed.

Table 3:10: Position of each dental school regarding the fifth component of the SPICES model

Birmingham	Manchester	King Abdulaziz	Taibah
Standard programme with an opportunity for students in their fourth year to undertake an individually tailored module, either an elective project on a subject of their choice, dental or non-dental, at home or abroad. In the fifth year, there is also an opportunity for them to choose a special study module in a clinical area of their choice.	A uniform core curriculum. During the fourth year, students do critical appraisal topic and they have the choice of the topic.	Uniform programme with no availability of elective courses. Students can choose their research subject area which they need to submit in the final year.	Standard programme with two elective courses are available for students during their third and fourth years. A predetermined lest of elective courses covering non-core subjects such as dental photography and evince based dentistry are offered by the school. Students also have the opportunity to choose their research project subject area during their fifth year.

3.4.3.6 Systematic Vs apprenticeship based

The last component of the SPICES model is described in Table 3:11. Table 3:12 presents the main differences between the schools with regard to this component.

Table 3:11: The main differences between systematic and apprenticeship training, adapted from (Mehay, n.d.)

Systematic	Apprenticeship
SUMMARY Training is more defined and structured *e.g.* a checklist of the type of conditions that must be seen and managed (or rotating through specified specialties) Core competencies identified and labelled Teaching is structured and organised Many teachers may be involved; developing a 1-1 relationship might prove difficult Better for revalidation and accreditation purposes	SUMMARY Learners exposed to a fair proportion of the patients that pass through the system over a fixed period of time Over time, learners may see a fairly representative sample of problems they are expected to deal with What is taught depends on the deficiencies identified based on what has come through Teaching is largely opportunistic; some say it should not be left to chance. Helps build a close 1-1 relationship between learner and teacher and yields a sense of belonging to the learner

Table 3:12: Position of the four dental schools in relation to their characteristics of clinical training

Birmingham	Manchester	King Abdulaziz	Taibah
A mixture of both systematic and apprenticeship training is detected. There is a check list of procedures and requirements for students to complete before their graduation. However, if a student did not have the opportunity to do certain important dental procedure on real patient, he/she is required to do it on a simulated natural tooth.	A mixture of both. Apprenticeship element and systematic training. The curriculum is competency-based with no certain number of requirements that students need to fulfil in order to pass a year. Instead, the number of training procedures is evaluated against the average of the students in each class.	Systematic training is used. There is a check list of dental procedures that should be completed by the students.	Training of students followed a systematic approach with certain requirements for the cases being managed and treated.

3.4.3.7 Other important aspects for the present research:

Other elements were added to the comparison of the four dental schools in order to relate it to the current research. These elements were felt to be important to understand the impact of curriculum on clinical reasoning development in dental school. We think that assessment method could have an impact on students' clinical reasoning. The use of different assessment methods appeared to have an impact on the reasoning process. This will be further discussed in Chapter 5. The timing of clinical exposure and the opportunities for students to practice their clinical reasoning could also affect their level of clinical reasoning skill. Please refer to Chapter 2 for more explanation of the role of clinical experience in gaining expertise required for clinical reasoning development. Table 3:13, Table 3:14 and Table 3:15 discuss the differences between the four dental schools according to their assessment, clinical exposure and clinical reasoning opportunities provided for students respectively.

3.4.3.7.1 Assessment

Table 3:13: Differences in assessment characteristics between the four dental schools

Birmingham	Manchester	King Abdulaziz	Taibah
Throughout the course, there are major professional examinations each year. There is also a range of different assessment methods and many of these are designed to develop generic skills as well as subject specific ones, for example presentation skills, data analysis and critical appraisal. Students also undertake formative assessments throughout the course, helping them to identify areas which they need to improve. In the clinical areas, continuous assessment is the major way in	Students should pass their examinations and course work in order to pass each year of their undergraduate study. Students should pass all the competencies required for their year of study in order to sign up for the end of year examinations. During their fourth year, students need to choose a topic for critical appraisal. In final year, students do a clinical audit project. Formative and summative assessment is used *e.g.* OSCE, short answers, SPAs and SAQs for 2nd, 3rd and 4th years. Final year students are also assessed through integrated patient care cases and unseen case. All assessment tools are in an integrated format set by exam board	Summative assessments are taken place at the end of each year. Every division is responsible to set their own format.	Every department is responsible to set their final year exams. Integrated courses have an integrated type of assessment.

which students are assessed, being given grades and feedback for each patient in each clinical session. This is supplemented by clinical examinations and competency tests.			

3.4.3.7.2 Clinical exposure

Table 3:14: Levels and characteristics of clinical training of each dental school

Birmingham	Manchester	King Abdulaziz	Taibah
Students have early contact with patients during their first year observing and reflecting on treatment sessions in the dental hospital. During the second year, further sessions with are available with senior students, assisting them during their patient care.in addition, peer working in taking medical histories, carrying out dental examinations and also	From the first year students take patient assessment Non-requirement-based curriculum. Average of each year is calculated with 1 or 2 standard deviation from the mean Students start treating their own patient in the second year, denture case.	Actual patient treatment starts in the fourth year of the six-year programme. Students have the opportunity to observe and take patients history during their third year.	Early contact with dental patients happens during the first year taking the course of dental public health. When students observe different kinds of patients including geriatric and the handicapped and recognize their needs. During the second year, students have some clinical experience of anaesthesia application. Students started managing their own patient. The curriculum has recently been changed to be patient-centred

learning how to administer local anaesthetics also takes place. The third year is the start of dental treatment by the students on their own patients at the hospital and outreach clinics.			rather than the previous requirement-based format.

3.4.3.7.3 Clinical reasoning opportunities

Table 3:15: Clinical reasoning opportunities provided for students in each dental school

Birmingham	Manchester	King Abdulaziz	Taibah
Critical thinking and problem-solving skills are claimed to be developed by the end of the course.' The ongoing strand of whole patient care in Clinical Practice enables students to integrate speciality teaching and perform the most appropriate treatment for patients aiming to make students independent thinkers with the ability to critically appraise the evidence-base for	Being a PBL course, students are exposed to elements of clinical reasoning from day one. As described by the course director. Revision symposia are also taken place during the fourth year so students have opportunities to gather information and deal with much clinical case.	Terms such as critical thinking are mentioned in the aims and objectives stated in the curriculum documentation. Developing competency in effectively diagnosing different dental problems is also stated in the course objective. However, the term clinical reasoning is not directly mentioned, but intention to develop this skill is clearly	The term clinical reasoning is not clearly mentioned in the curriculum documentations objectives, but the course of integrated dentistry aims to enable students to develop and improve their clinical skills through setting out a treatment plan, differential diagnosis and different therapeutic and surgical treatment modalities for each patient's problem. Moreover, an intention to develop clinical reasoning skills can be

clinical dentistry is also mentioned in the website. Students are expected to think, discuss and engage critically with the subject and find things out for themselves.		presented during the clinical years.	identified in the objectives of the clinical phase of the programme mainly to reach a diagnosis. Critical thinking skills development is also mentioned as an objective in the oral medicine and evidence-based dentistry courses. The term problem solving is mentioned in the objectives of some courses.

3.5 Discussion and conclusion

The type of undergraduate curriculum appeared to play a role in the development of dental and medical students' clinical reasoning skills especially during their early years of undergraduate education (Da Silva, 2013, Groves et al., 2003a, Schmidt et al., 1996). However, curriculum impact on the level of clinical reasoning is argued to diminish when students approach their final years (Da Silva, 2013, Groves et al., 2003a). The findings of our quantitative analysis of the differences in the level of clinical reasoning based on different curricula also suggested minimal curriculum effect as we targeted final year dental students, see Chapter 4. However, the characteristics of the reasoning *process* appeared to be affected by the type of undergraduate curriculum (Barrows and Pickell, 1991, Patel et al., 2005, Pardamean, 2012a), see Chapter 5.

In the current research we aimed at studying the curriculum effect on clinical reasoning targeting dental students at different schools. In order to introduce our studies we explained the differences between the undergraduate curricula of these different schools. Analysis of their curricula was based on the SPICES and the Integrated Ladder models (Harden, 2000, Harden et al., 1984).

One participating school implements PBL, which is the Dental School at the University of Manchester, whereas the curricula of remaining other dental schools preserve the separation between preclinical and clinical phases of dental education. The two UK dental schools at the University of Birmingham and Manchester show elements of student centred approach being more prominent at Manchester. Although the curriculum objectives at Taibah Dental School do not reflect students input, students may choose their preferred elective courses and project topics unlike King Abdualziz students.

The level of curriculum integration varies among the participating schools. Manchester being the highest with inter-disciplinary integration, which is the tenth step in the Integrated Ladder framework. This level of integration is presented by focus of the curriculum on specific themes and the integration of teaching around these themes. Birmingham and Taibah Dental Schools are nearly at the same level of integration, but the former showed a slightly higher level. They both present Correlated curricula, the seventh step in the Ladder. This level of integration involves integrated courses running besides the discipline-based teaching. King Abdualziz School applies a mainly isolated discipline-based program. Although an integrated course is present in the final year, its main aim is to assess the students' level of competence rather than integrated teaching. This is because this course is delivered at the end of undergraduate education when students have already achieved the required level of biomedical science knowledge.

Community-based clinical training for students is a feature of the undergraduate curricula at the four dental schools. All of the four schools also offer uniform BDS courses with availability of different elective courses at most of them. Systematic approach with the presence of a check list of requirements for dental procedures is applied at the two Saudi Schools. A mixture of systematic and apprenticeship approaches characterise the two UK Schools.

In conclusion, there is a debate about the best curriculum model to enhance students' clinical reasoning ability. In general there was no intention to evaluate curricula at the participating dental schools rather a curriculum analysis was conducted to explain the context of the current research. This analysis has revealed differences between them.

We expect that the reader is now aware of the main characteristics and differences between the undergraduate curricula of the dental schools involved in the quantitative and qualitative studies being discussed in the following two chapters.

4 Chapter 4: Clinical reasoning in dental students: a quantitative study

'Education is not the learning of facts; it's rather the training of the mind to think.'

(Einstein)

Chapter outline

This chapter will discuss the quantitative part of the current research. The creation of a purposely designed clinical reasoning assessment tool will be discussed. The application of this special test to different groups of final year dental students from three different curricula will be presented and the results will be analysed in order to understand the curriculum impact on clinical reasoning and the possibility of other factors to have an impact on its development *i.e.* gender and knowledge. Discussion of the findings of this cross sectional comparative study will also be presented together with the limitations and conclusion.

4.1 Introduction

Our discussion of the clinical reasoning literature, in Chapter 2, indicates that only a few investigations have described clinical reasoning in dentistry (Maupome et al., 2010, Maupome and Sheiham, 2000). There is a current need to develop suitable assessment methods for this essential skill in dentistry as stressed by Khatami *et al,* who also reported that the need for developing an assessment tool has still not reached a satisfactory level (Khatami, 2010, Khatami and MacEntee, 2011). However, developing a suitable assessment tool is not an easy process. There is a general agreement on the fact that one of the difficulties surrounding clinical reasoning arises during attempts to formulate suitable assessment tools (Neufeld et al., 1981, Norman, 2005, Higgs and Jones, 2008a).

As there is a consensus about the paramount importance of clinical reasoning, there are multiple attempts to develop assessment tools that are both valid and reliable. Some of these tools assess the product of the clinical reasoning such as the Key Features Test (KF), while others are more concerned with the process itself *e.g.* the Script Concordance Test (SCT). The heterogeneous tools used to assess clinical reasoning, described in Chapter 2, reflect the developer's understandings of the concept of this important skill. These tests can be also characterised by their varying degrees of validity and reliability. Groves (2002) argued that there is no tool or measure that could best assess clinical reasoning process or end product while being both valid and reliable. Instead, one should carefully consider the aims, objectives and reasons for this assessment in order to choose the test that best meets those.

However, mixing more than one type of clinical reasoning assessment tools may combine their advantages and increase the usefulness of the test. One of the innovations reported to assess clinical reasoning skills was described by Amini *et al* (2011) when they used a multi instrument test (a combination of KF, SCT, Clinical Reasoning Problems (CRP) and Comprehensive Integrative Puzzles (CIP)) to combine the multipurpose of these tools. This test was having different parts corresponding to the multiple assessment components. The test was used to assess talented undergraduate medical students in a national medical science Olympiad in Iran. It was shown, although the results may not be generalised as stated by the authors, that this innovative method was highly reliable (Cronbach's Alpha 0.9). We believe that if this combination was successful for the assessment of clinical reasoning in high stakes examinations, then it might be useful to implement it for a cross sectional study to understand the relationship between the type of undergraduate dental curriculum and the development of clinical reasoning skills in dental students.

Another example of combining more than one assessment tool to test clinical reasoning has also been reported in the literature. A study to find the effect of emotional intelligence and personality on the level of clinical reasoning skills among medical students has used a test that comprises three separate parts using different assessment tools for clinical reasoning. These tools were CIP, KF and CRP (Stys and Brown, 2004). More recently, Da Silva (2013) used an innovative test, which was developed to assess clinical reasoning in undergraduate medical students. This test consisted of two long cases with varied question types including CRP and SCT, using a marking scheme similar to DTI, in order to combine the advantages of these test formats. The test was shown to be both valid and reliable. More explanations of DTI and other assessment methods were presented in Chapter 2.

In this chapter, a cross sectional quantitative research study will be described, in which a new way to test clinical reasoning in undergraduate dental students was developed as a mixture of three different assessment tools for clinical reasoning in a single test. This study aimed to:

1. Evaluate the effectiveness of this innovative method in assessing clinical reasoning in dental students.
2. Examine the possible effect of participants' gender and on their level of clinical reasoning skills.
3. Examine the possible relationship between the type of undergraduate curriculum model and the development of these important skills by applying the test to participants who were selected from three different dental schools, two in the UK and one in Saudi Arabia (SA).

The following section will describe the materials and methods used.

4.2 Material and methods

This study was approved by the Ethical Committee of the University of Nottingham, (see Appendix 1). A new clinical reasoning test (CRT) was developed using a combination of assessment tools based on an understanding of their theoretical framework and suitability for testing various elements of clinical reasoning, as follows:

- A modified version of the KF test was used to measure the skill of gathering of important information from patient history.
- A Patient Management Problem (PMP) was used for the assessment of hypothesis formation and the ability to work through a specific case.
- A SCT was used to measure hypothesis evaluation.
- A small number of questions testing pure biomedical science knowledge.

4.2.1 KF items

KF items of the test were modified to include only three open-ended questions in contrast to the original test which had a large number of questions that require four hours of testing to reach an acceptable level of validity (Farmer and Page, 2005). The results of reliability testing for the KF items of the test showed low value for Cronbach's alpha as a function of fewer questions as illustrated Table 4:7. However, the reliability value for the whole CRT was within the acceptable range as will be described below.

4.2.2 PMP items

The longitudinal nature of the PMP was maintained throughout the entire test, which means that each dental case was presented in a logical order similar to discussing an actual clinical case starting with the patient's history and clinical features and finishing by a management plan.

Neufeld *et al* (1981) suggested that problem-solving ability is not a single skill that can be assessed separately from other competencies such as: knowledge application, selection of data in order to generate hypotheses and evaluation of the need for more data, history taking and physical examination techniques, and communication skills. For that reason, the CRT was aimed to include most of the elements involved in the clinical reasoning process. The test items were categorised into different groups and are presented in Table 4:1, based on each clinical reasoning skill they were suggested to be testing. These suggestions of the categories were based on inputs from experts in the field of dentistry and medical education together with the results of literature review in the skills required for the clinical reasoning process.

The test was case-based so that the participant went through multiple questions regarding selection of data, gathering of information, hypothesis generation, interpretation of findings, dealing with new information, hypothesis testing, providing final diagnoses and selection of management options, in addition to a small number of questions testing basic knowledge. In contrast to the original PMP test scoring system which concentrated on the ability of data gathering rather than making appropriate decisions, decision making was also included as a component to be tested in the developed CRT (Farmer and Page, 2005).

4.2.3 SCT items

The developed CRT had a total of only ten SCT items related to two of the cases in contrast to the original SCT, which has many questions requiring nearly one-hour of testing time (Lubarsky et al., 2009, Lubarsky et al., 2011, Piovezan et al., 2012, Lubarsky et al., 2013). It was found that reducing the number of questions did not affect the reliability values of the test, as will be presented later in the '*validity and reliability'* section.

4.2.4 Knowledge-based items

Van der Vleuten and Newble (1995) argued that 'since *knowledge and reasoning are closely linked we should not be afraid to test knowledge, but the challenge is to test it in a way that requires application to a concrete clinical situation'*. A decision was made to include two questions to test the biomedical science knowledge of the participants. However, these questions were imbedded in the PMP discussion of the clinical cases in the CRT and were included in the analysis as part of the PMP because they follow the sequence of discussion related to the clinical cases and were formatted as PMP items.

One of these questions was asking for a management option after a diagnosis was given. The other was concerned with providing common clinical features of a disorder after discussing its diagnosis. Correlation between the marks obtained from these two questions and the total test marks was strong and positive, as will be discussed later. This finding further supports the need to include this type of question because knowledge comprises an important part in clinical reasoning, as discussed in Chapter 2.

4.2.5 The CRT format

The test was divided into five dental cases in an attempt to refer to multiple dental divisions including restorative dentistry, paedodontics, periodontics, oral pathology and oral medicine. These cases tackle different dental problems that a general dentist may regularly encounter, including improper composite restoration, fluorosis, periodontitis in a diabetic patient, dental trauma in a child and problems with tooth eruption. In addition to the biological problems, a psychosocial component was also a feature of the test.

It is known that dental caries is still considered a major problem for oral health care in many industrialised countries (WHO, 2000, Petersen, 2003). The issue of dental caries is discussed in *the first case* but in a way that encouraged the participant to think about potential problems in caries management.

In *the second case* fluorosis was the main theme. Fluorosis is one of the oral conditions that require the dentist to think carefully through the history and clinical presentation of the teeth, in order to differentiate this condition from other conditions of tooth malformation and pigmentation which may share some features of the clinical presentation.

The third case concerned the management of periodontitis in a diabetic patient. As reported by the World Health Organization, the initial stages of periodontitis are prevalent with varying degrees among the different countries of the world (WHO, 2000). The importance of including this case was based on the increasing incidence of diabetes worldwide (Wild et al., 2004), and the proven adverse effects of unmanaged diabetes on the oral condition. Participants need to be able to identify the possible causes for poor soft tissue healing following periodontal surgery, and to identify certain features in the case presentation indicating a systemic condition that may affect healing. They also were asked to explain their reasoning in case the patient asks for extractions to be carried out for all his teeth with complete denture replacement because of an inability to afford the required dental treatment costs. This question was added to test the effect of psychosocial and ethical factors on making a decision. Answers to this open ended-question will be discussed in '*The qualitative differences for question 22'* under the Results section.

Because trauma is not an unusual problem in children (Şaroğlu and Sönmez, 2002, Marcenes and Murray, 2001, Kahabuka et al., 2001, Grimm et al., 2004, Borssén and Holm, 1997, Al-Majed et al., 2001), *the fourth case* covered a traumatic injury in a four-year old child. Participants were asked to elucidate the cause of trauma, which might indicate a case of child abuse, adding an element of psychosocial and ethical reasoning described by Khatami *et al's* (2011) framework of clinical reasoning in dentistry (see Chapter 2). They were also asked to choose an appropriate management option and justify their choice.

Finally, *the fifth case* in the CRT was about an un-erupted permanent tooth in a child, in which the participant needed to provide differential diagnoses and support his/her choices. Intraoral pictures and dental radiographs were provided throughout the test, in light of the acknowledged importance of visual cues in the pattern recognition approach of clinical reasoning that characterises dental students (Khatami, 2010).

The validity of the test was supported by having its content examined and commented on by nine dental educators in the Canada, UK and SA, indicating the suitability of these cases for their fifth year students. The test was kept relatively short (about 20 minutes) for the purpose of the study and due to the fact that students were volunteering to participate (although, they were encouraged to participate by being offered entry to a raffle for Amazon® vouchers).

The final version of the CRT was delivered in an online format using Survey Monkey software®. Browsing of the test was unidirectional, meaning that participants could only go to the next screen after completing the current one, but could not go back to a previous screen after moving on. This was done to prevent consequential help (the ability to correct earlier answers using information presented later in the test).

An online link was sent to all final year dental students through the gate keeper in each school. The choice of online survey was agreed upon to increase the response rate as participants can take the test any time at their convenience. Another advantage of the online testing is that it provides high resolution pictures for the cases without adding extra cost. Site visits to describe the purpose of the study and to recruit participants using a short PowerPoint® presentation were carried out following a lecture or a seminar.

Final CRT items were developed in different formats. The test had a total of 31 MCQs, yes/no and open-ended questions. Please refer to Appendix 3 for clarification.

The test items were classified using inputs from seven expert dentists and experts in medical and dental education. Categories were initially suggested by the researcher based on the components of the clinical reasoning process described in the literature (Higgs and Jones, 2008b). A copy of the CRT was electronically sent to the experts. They were asked to complete a table typing on questions' numbers under the suggested categories, with an option of 'cannot *be categorised'* and the possibility of typing on the same question in more than one category. Categories and subcategories of the test items are presented in Table 4:1 and Table 4:2. For a copy of the CRT please refer to Appendix 2.

Table 4:1: CRT items categories using inputs from experts and suggestions made by the researcher based on the literature regarding the components of clinical reasoning

categories	subcategories	Questions
Selection of information	Key features from the case presentation	Q1,Q6,Q26
	Selection of discriminatory questions	Q8
Processing of new information		Q9
Hypotheses generation	Generating diagnostic hypotheses	Q2, Q10, Q18, Q19, Q27
	Suggesting causes to the problem	Q17, Q21, Q22
Hypotheses testing, Script Concordance		Q11, Q12,Q13, Q14, Q15, Q16, Q28, Q29, Q30, Q31
Decision making	Selection of required investigations	Q3, Q23
	Management options	Q4, Q7, Q20, Q24
Knowledge based questions	Preventive measures	Q5
	Management options	Q25

Table 4:2: Classification of the CRT items according to their type of clinical reasoning assessment tool

Key Features	Patient Management Problems	Script Concordance
Q1, Q6, 26	Q2, Q3, Q4, Q5, Q7, Q8, Q9, Q10, Q17, Q18, Q19, Q20, Q21, Q22, Q23, Q24, Q25, Q27	Q11, Q12, Q13, Q14, Q15, Q16, Q28, Q29, Q30, Q31

4.2.6 Scoring the CRT

Test results were scored both manually, for the short text answers (looking for key words) and electronically for the multiple choice questions. The total mark of each question varied according to the input required to answer the question. Some questions have a total mark of 1, some have 2 and some have a total mark of 3. All marks were given as a numeral without fractions. Blank and incorrect answers were given a mark of zero. The marks for the short text answers and the MCQs were then added to the marks for the 10 SC questions.

Marking of the SC items, was followed using the original marking scheme described in Chapter 2.The total mark available for the CRT was calculated as 45 marks, 10 of which came from SC items. For the test marking please refer to Appendix 3.

4.2.7 Statistical analysis

Normality tests were carried out for the data in order to decide on the suitable statistical tests (whether parametric or non-parametric) to be used in the analysis. These normality tests can be done either graphically or numerically (Lofgren, 2014). To test the normality of data the following numerical and visual outputs must be investigated, as follows:

- Skewness and Kurtosis z-values (should be between -1.96 and 1.96 for normal distribution)
- The Shapiro-Wilk test p-value (should be >0.05 for normal distribution)

- Histograms, when data are presented as an inverted bell shape of nearly equal sides, this could reflect a normal distribution.
- Normal Q-Q-plots, data points would be close to the diagonal line if data were normally distributed
- Box plots, if outliers appear on one side of the box and if the mean does not lie on or near the central line of the boxplot, data are suggested to have a skewed distribution.

Statistical analysis was carried out using IBM SPSS statistics 21® software.

As suggested by Tavakol and Dennick (2012), post examination psychometric analysis of medical examination data is required in order to provide an assessment tool with high quality. This in turn will help to improve the teaching and learning process. The post examination psychometric analysis of exam data was traditionally conducted by using Classical Test Theory (CTT). The main concept of this theory is to consider the raw score of a test as being made up of a true score plus random error. It is concerned with methods to effectively deal with the random error, as a smaller the random error leads to the test score being closer to the true score (Kline, 2005). CTT has been in use for more than 80 years. However, recently there has been increased use of Item Response Theory (IRT) as it is applied to many tests such as the Scholastic Aptitude Test (SAT) and several individual intelligence tests. This is because of its many advantages over CTT. CTT does not consider the interaction between individual’s ability and the test items. It only focuses on the test and its error (Embretson and Reise, 2000, Tavakol and Dennick, 2012).

Despite the increasing use of IRT, its use in the field of medical education is still limited (Tavakol and Dennick, 2012). One of the useful characteristics and fundamental features of IRT is the concept of psychometric information. The interaction between student ability and item difficulty is taken into consideration so that test items can be checked against student ability to provide a high quality test. By using item-student maps problematic test items can be identified (often these test items are either too easy or too difficult). The assessment tool can then be amended in a way that matches the ability of the targeted students, as described in the pilot phase of the study. In this case the quality of CRT can be examined and better reflects the level of clinical reasoning of the student sample. This analysis was carried out using Winsteps® software.

Factor analysis was also applied to the data in order to study the test items correlation and loading to different factors, reduce the data and remove redundancy and noise in the test items by removing irrelevant questions (Garrett-Mayer, 2006).

4.3 The pilot phase

Before piloting CRT, the test was reviewed by a panel of twelve experts in different fields of dentistry and dental & medical education. This convenience sample of experts was from SA, the UK and Canada. One of those experts is Professor Charlin, the developer of SCT. Another expert who validated the CRT is Dr. Khatami, who developed the framework of clinical reasoning in dentistry, (as discussed earlier on page 119), in addition to other dental educators. Changes were made to some of the test questions in response to experts' reviews. Some of the changes included adding more visual cues as many dental conditions are dealt with by pattern recognition, changing some wording, and adding some questions.

A pilot study was then carried out using a convenience sample of thirty final year undergraduate students from dental schools at three different universities namely: the University of Birmingham and the University of Manchester in the UK and Taibah University in SA. These dental schools have implemented different curriculum models for their undergraduate BDS (Bachelor of Dental Surgery) courses. For a detailed description of their curriculum models please refer to Chapter 3.

Responses of another cohort of thirteen experts (with more than ten years of experience in dental practice) were also included in the study. This convenience sample of experts was both from the UK and SA. Participants were informed about the study objectives via e-mails containing a link to the online clinical reasoning test. Results were anonymous and the researcher was only able to distinguish experts from students. Students' names or any personal identification of students were not required when taking the test. Demographic data was also collected including gender and the name of the school. Students' participation in the study was encouraged by a raffle of Amazon® vouchers.

This pilot study was conducted towards the end of the academic year 2012-2013 a few weeks before the start of the final examinations so as to ensure that the CRT was being used to test the skills of students with the maximum level of knowledge and practical training. By choosing final year students we also hoped to avoid the origin bias of test items on the test results, which can compromise the validity and fairness of curriculum comparison (Muijtjens et al., 2007). This was a potential concern because I, the creator of the CRT, graduated from King Abdulaziz dental school and I thought it would be better to avoid any possible bias of experiencing one of the curricula involved in the study. In addition, different subjects are taught at different year groups of the program which is specific to every school based on its curriculum model. As a result, choosing final year dental students as participants would ensure that almost all students would have gained all the required teaching and training needed to be future dentists.

The results of this pilot study showed that the value of Cronbach's alpha was as low as 0.61 for the students' sample, and 0.62 for the experts sample. These values were low compared to the recommended range of 0.7 to 0.95 (Tavakol and Dennick, 2011). However, the low sample size could be a contributing factor to this low level of reliability. Furthermore, some of the multiple choice questions had a large number of choices which made them create noise rather than being good distractors. This might also have contributed to the low value of reliability.

In order to carry out comparative statistical analysis, data obtained from both students and experts' samples should be tested for normality. To test the normality of our data numerical outputs, for skewness and kurtosis, were investigated. *Z* values for the student sample were calculated as follows:

- Normality of skewness= -0.552/0.427=**-1.293**
- Normality of kurtosis= 0.116/0.833=**0.139**

Again, *z* value was calculated in the same way for the experts' sample, as follows:

- Normality of skewness= 0.113/0.616= **0.183**
- Normality of kurtosis= -0.927/1.191=**-0.778**

Those *z* values for skewness and kurtosis were falling between -1.96 and 1.96. Data were considered normally distributed for both students' and experts' samples. Therefore, parametric statistics were used to do the comparison between the two samples in the pilot study.

4.3.1 Comparing the experts and students results in the pilot phase

In order to compare the total marks obtained for students and experts in the pilot phase, an unpaired T test was used. There was a significant difference between the mean values of the total test marks for students (M=31.85, SD=4.53) and experts (M=36.10, SD=1.47) conditions; t (41) =-3.29, *p*=0.002.

These results suggest that experts performed significantly better than students participating in the pilot phase of our study.

The statistical analysis of the results obtained from the pilot phase used the concept of ITT. Figure 4:1 and Figure 4:2 show student-item and expert-item maps of the pilot phase of the study.

Person (student)-item map is a useful visual display of the relationships between students' abilities and test items difficulties. This is displayed in a linear scale using logits as units. Student ability is displayed on the left side of the vertical line as x and items information is presented on the right as "q" for non-script concordance questions, and "s" for script concordance questions. In the map "M" represents mean for person and item, "S" represents one sample standard deviation away from the mean, and "T" represents two sample standard deviations away from the mean. The higher the position of a student in the map, the higher is his/her ability to correctly answer the test and vice versa. The position of a test item on the map is an indication of its difficulty. The most challenging items are located at the top of the map, while the easier items are located towards the lower end. A test is considered as well-targeted at the intended sample of students if the cluster of students is located opposite to the cluster of the items (Bond and Fox, 2007, Oon and Subramaniam, 2011).

In the case of our CRT we found that although some of items were clustered against students' ability, others were not perfectly matched to the students' ability. Also it was clear that the ability of the student sample was relatively high. This can be explained by the low sample size and the fact that they were all final year students close to graduation. Some questions were located in the bottom half of the map meaning that they were easy for the targeted student sample. The person-item map shown in Figure 4:2 indicated the high ability of the experts sample compared to items difficulty.

```
 2             X   +T
                    |
                   T|
                    |  q12
               X    |
               X  S|
      XXXXXXXXXXX   |  S3     S6     q4
    XXXXXXXXXXXXX  M|  S1     S10    S2     S4     S5     S7     S8     S9
                       q23    q3
 1                  +S
                   S|  q2
              XX    |
                   T|  q10
                    |  q22
                    |
               X    |  q13    q16    q20    q21    q9
                    |
 0                  +M
                    |
                    |
                    |
                    |  q18    q19    q6
                    |
                    |  q15    q8
                    |
-1                  +S q14
                    |  q7
                    |  q1
                    |
                    |
                    |  q11
                    |
                    |
-2                  +T
                    |
                    |  q17
                    |
                    |
                    |
                    |
                    |
-3                  +
                    |
                    |
                    |
                    |
                    |
                    |
                    |
-4                  +  q5
```

Figure 4:1: Item-student map for the pilot study: each x represents an individual student. The values on the left of the scale are logits. (*q*) represents a test question followed by question's number, *M*=mean, *S*= 1 standard deviation from the mean, *T*= 2 standard deviations from the mean. Some of the test items do not match the high students' ability.

```
 3       X  +
         X  |
         X  |
            |
            |
         X S|
            |
         X  |
         X  |
         X  |
 2          +
            |
           M|
            |
            |
         X  |  Q16    Q29
            |  Q11    Q28    Q30    Q31
        XX  |T Q14    Q15
      XXXX  |  Q13
         X S|  Q12
 1          +
         X  |  Q20
            |  Q8
            |
            |S Q2     Q7
            |
           T|  Q1
            |
            |  Q18    Q19    Q23    Q25    Q26    Q3     Q4
            |
 0          +M Q24    Q27    Q6
            |
            |  Q17    Q22
            |
            |
            |  Q9
            |S
            |
            |
            |
-1          +
            |  Q21    Q5
            |
            |T
            |
            |
            |
            |  Q10
            |
            |
-2          +
```

Figure 4:2: Item-expert map for the pilot study: The values on the left of the scale are logits. *Q* represents a test question followed by question's number, *M*=mean, *S*= 1 standard deviation from the mean, *T*= 2 standard deviations from the mean. Most of the test items are easy for the experts' sample.

In summary, issues encountered from the results of the pilot phase can be summarised, as follows:

- Low sample size, (as expected)
- Moderate reliability value, indicated by the value of Cronbach's alpha
- Item-student map indicating that most questions were seen as easy

4.4 The final clinical reasoning testing phase

In response to the analysis of the data obtained from the pilot study, measures to enhance the student-item interaction and to increase the test reliability were taken. The test was amended and problematic items were removed and altered in order to increase their difficulty level. Some redundant items were also excluded to reduce the noise when conducting statistical analysis. These changes were thought to support the content and face validity of the test, as judged by experts in the field (Lynn, 1986).The amended version of the test was checked again by a panel of three experts for its content and face validity. Then the final version of the clinical reasoning test (CRT) was prepared in its online format. The iterative process of the CRT development is illustrated in Figure 4:3.

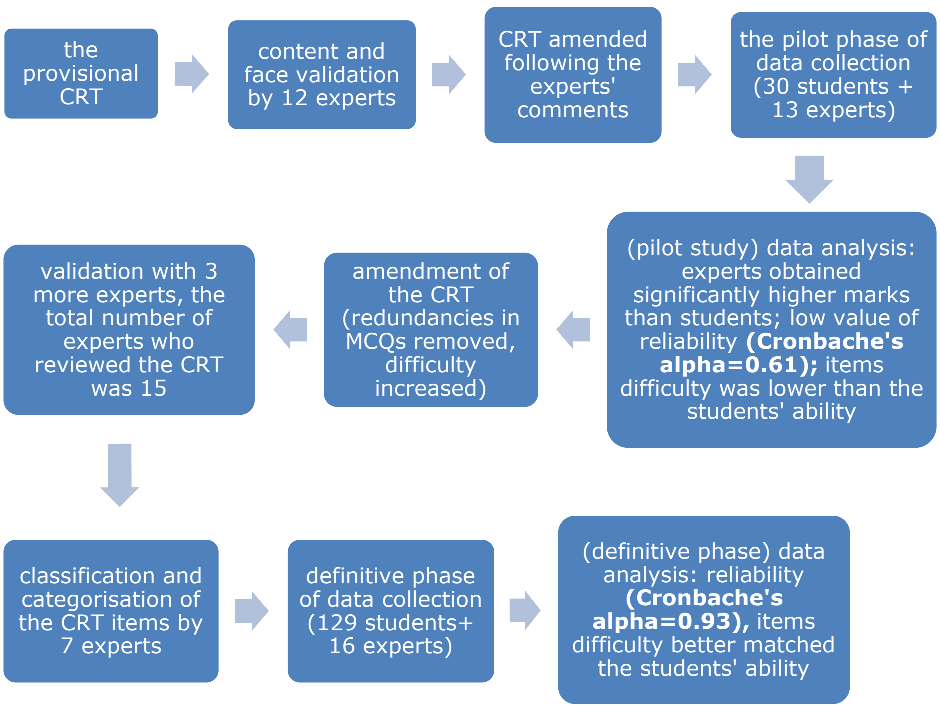

Figure 4:3: Phases of the CRT development

4.4.1 Participants

Initially, there was an intention to include participants from the Dental School at Taibah University in SA. However, despite the effort made to recruit the final year students, the response rate was very low. Only three students out of 17 responded. A decision was made not to include responses from students at Taibah University and to replace them by KAU responses, for the following reasons:

1. The response rate was considered very low
2. All of the students in Taibah University sample were male, which would not help in studying the potential effect of gender on the level of clinical reasoning skills development
3. The undergraduate curriculum model at Taibah University, as shown in Chapter 3, is different to that of King Abdulaziz Dental School (both in the model and number of years) so the two samples cannot usefully be combined, despite the fact that they both share the same culture.

After the pilot phase, the final version of the online test was prepared and all final year students at the three dental schools were invited to participate in the study via e-mails sent to them by gatekeepers at their schools. An information letter and a consent form were attached to the email, (see Appendix 4). Two other reminder e-mails were also sent by the gatekeepers to the students in order to increase their response rate.

Table 4:3 and Table 4:4 present the demographic data of the students' sample. The University of Birmingham had a total of 77 final year dental students, the Dental School at King Abdulaziz University had a total of 96 final year students and the total number of final year dental students was 81 for the University of Manchester. The response rates were different for each school being 50% for Birmingham, 51% for King Abdulaziz and 45% for Manchester samples. Data collection was carried out over three months. Participants were targeted approximately in the middle of their final year in 2013.

Another convenient sample of sixteen expert dentists with more than ten-year experience in dentistry also participated in the study, seven of which were females. They received the same electronic version of CRT as the student sample with an information letter, (see Appendix 5).

Table 4:3: Number of participating students from the three dental schools in the final phase of the study

School	Number of participants	Response rate
Birmingham	39	50%
King Abdul-Aziz	53	51%
Manchester	37	45%

Table 4:4: Gender distribution of the student sample in the final clinical reasoning testing phase from the three dental schools

Students' Gender	Number of participants	Percentage
Male	31	24.03%
Female	98	75.97%

4.4.2 Results of the final CRT

4.4.2.1 Validity and reliability

4.4.2.1.1 Content and face validities

Validity is usually divided into content, construct and concurrent categories. *Content* and *face* validities were carried out during the pilot phase, as described earlier, and repeated again for the final CRT version by convenient samples of well-trained dental educators and specialist in medical education. The total number of experts participating in the validation process was fifteen. Those experts ensured that the test organisation and its content were matched to its objectives and specifications and thus provided both content and face validity.

4.4.2.1.2 Construct validity

In order to examine the evidence of *construct* validity of the CRT, the normality of the data should be checked first in order to identify the statistical tests to be used. As will be described in the following section, in the *'test of normality'* section, graphical and numerical analysis showed that some of our data was not normally distributed. Consequently, non-parametric statistical tests were used to deal with data obtained from using the final version of CRT. Construct validity of a test can be described as the ability of a test to measure the construct defined in its aims. If the test proved that it supports the theories of its construct, then it can be considered to have construct validity (Brown, 2000).

In case of the current study, clinical reasoning was the construct aimed to be measured. In the literature, it has been theoretically agreed upon that experts always perform better than novices in relation to their clinical reasoning abilities; please refer to Chapter 2 subheading '*Common characteristics of novices and experts reasoning*' on page 61 for the supporting evidence. Construct validity of the CRT can be reflected by the significance of the difference between experts' results and students' results.

The mean values of the total CRT marks of the students' and experts' samples (presented in Table 4:5) indicated that there was a considerable difference between the two samples, being 25.95 and 35.71 respectively. The Mann Whitney U test was used, as a non-parametric test, to compare the means of the two groups, (see Table 4:6). The results showed that *p* value = 0, meaning that there was a significant difference between the experts and students samples in their clinical reasoning test results. This fact supports what is known about clinical reasoning being better in experts compared to students. In fact, the amended CRT showed evidence of construct validity.

Table 4:5: The mean value for the students' and experts' total CRT marks in the final testing phase

Sample	Number	Min. score	Max. score	Mean	Std. Deviation
Students	129	8	43	25.95	9.58
Experts	16	25.90	42.81	35.71	5.50

Table 4:6: Mann-Whitney U test showing the statistically significant difference between the mean values of the CRT scores for the experts and students in the final test phase, $p=0$

Mann-Whitney U	364.00
Z	-4.22
Asymp.Sig. (2-tailed)	0.00

4.4.2.1.3 Concurrent validity

Time restraints, together with the nature of the current study make it difficult to test indications of *concurrent* validity of the CRT. This type of validity can be defined as the presence of evidence that the results of the test being validated are correlated to results obtained from some well-respected outside measures intended to share the same objectives (Brown, 2000).

4.4.2.1.4 Reliability values

Reliability values for each type of items, (presented in Table 4:2), were calculated separately as presented in Table 4:7 . These reliability results showed a low value for the KF items of the test (Cronbach's alpha= 0.51), which could be a function of the small number of questions for this category.

Cronbach's alpha was calculated for the whole CRT as well. It was 0.93 for the combined students' sample from the three different schools indicating that the test was reliable. For the experts' sample, who took the final CRT, the value of Cronbach's Alpha was 0.84, which could reflect the effect of a lower sample size. Never the less it is still within the acceptable range of reliability.

Table 4:7: Reliability values for the different types of questions involved in the CRT for the student sample

Type of Item	Cronbach's Alpha	Number of Items
Key Features	0.51	3
PMP	0.90	19
Script Concordance	0.79	10

4.4.2.2 The interaction between participants' ability and the final CRT items as measured by Item Response Theory

Again, the person-item maps were created for data obtained from the amended CRT test to examine the effect of enhancement carried out to improve the CRT. Figure 4:4 and Figure 4:5 illustrate this interaction. The results indicated the high ability of the experts' sample compared to item difficulties and a good matching in case of the students' sample.

```
 3            .  +
              .  |
                 |
              .  |
              .  |
              . T|
              .  |
                 |
 2            .  +
              .  |
              #  |
             .#  |
              #  |
             .# S|
             .#  |
              .  |
 1               +
                 |T
                 |
                 |  Item16  Item23  Item3
     .#########  |S Item19  Item2   Item20
         .##### M|  Item25
             .#  |  Item13  Item14  Item31  Item7
            ###  |  Item10  Item27  Item28  Item29  Item30
 0            .  +M Item15  Item17  Item21  Item22
              .  |  Item11  Item12  Item18  Item26
             .#  |  Item1   Item6
             .#  |  Item4   Item5
              #  |S Item9
              # S|
              #  |
              .  |T Item8
-1           .#  +  Item24
              .  |
              #  |
              .  |
              #  |
              . T|
                 |
                 |
-2                    +
```

Figure 4:4: Item-student map for the final phase of the study. Each # represents four students. The values on the left of the scale are logits. Items of the test are presented with their number of order in the CRT, *M* =mean, *S* = 1 standard deviation from the mean, *T* = 2 standard deviations from the mean. Most of the test items match students' ability.

```
 3       X  +
         X  |
         X  |
            |
            |
         X S|
            |
         X  |
         X  |
         X  |
 2          +
            |
           M|
            |
            |
         X  |  Q16    Q29
            |  Q11    Q28    Q30    Q31
        XX  |T Q14    Q15
      XXXX  |  Q13
         X S|  Q12
 1          +
         X  |  Q20
            |  Q8
            |
            |S Q2     Q7
            |
           T|  Q1
            |
            |  Q18    Q19    Q23    Q25    Q26    Q3     Q4
            |
 0          +M Q24    Q27    Q6
            |
            |  Q17    Q22
            |
            |
            |  Q9
            |S
            |
            |
            |
-1          +
            |  Q21    Q5
            |
            |T
            |
            |
            |
            |  Q10
            |
            |
-2          +
```

Figure 4:5: Item-expert map for the definitive phase of the study. Each x represents an individual expert. The values on the left of the scale are logits. *Q* represents a test question followed by question's number, *M*=mean, *S*= 1 standard deviation from the mean, *T*= 2 standard deviations from the mean. Most of the test items are easy for the experts' sample. Experts' ability can be seen as high compared to the test items.

In summary, most of the deficiencies in the piloted CRT had been overcome in the final version of the test, as follows:

- Reliability increased from 0.61 to 0.93

- The interaction between the test items and the students' ability was better matched than it was in the pilot test as judged by IRT

Therefore, the final CRT was thought to be both valid and reliable as well as being more suitable to the students' level of ability. Statistical comparisons can now be carried out with confidence.

4.4.2.3 Test of normality (gender)

Before carrying out statistical analysis of the data obtained, normality tests are required. Firstly, normality was checked for the students' sample in relation to their gender. Then normality tests were also carried out for each cohort of students participating from the three dental schools. As described earlier (in section 4.2.7) this can be done either graphically or numerically (Lofgren, 2014). The following visual and numerical outputs were investigated as follows:

- Histograms, (see Figure 4:6 & Figure 4:7)
- Normal Q-Q-plots, (see Figure 4:8 & Figure 4:9)
- Box plots, (see Figure 4:10)
- Skewness and Kurtosis *z*-values
- The Shapiro-Wilk test *p*-value

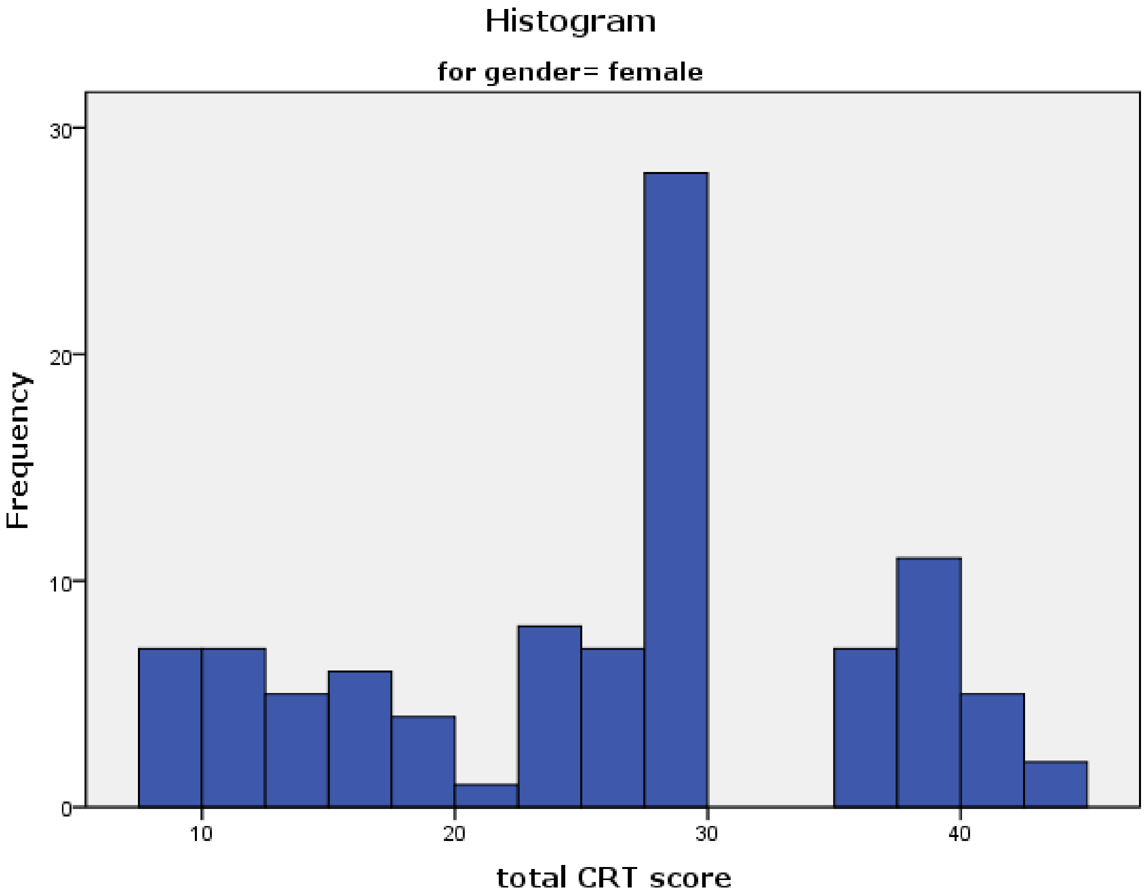

Figure 4:6: Histogram presenting the total marks of female student sample who took the final version of the CRT reflects the non-normal distribution of the data

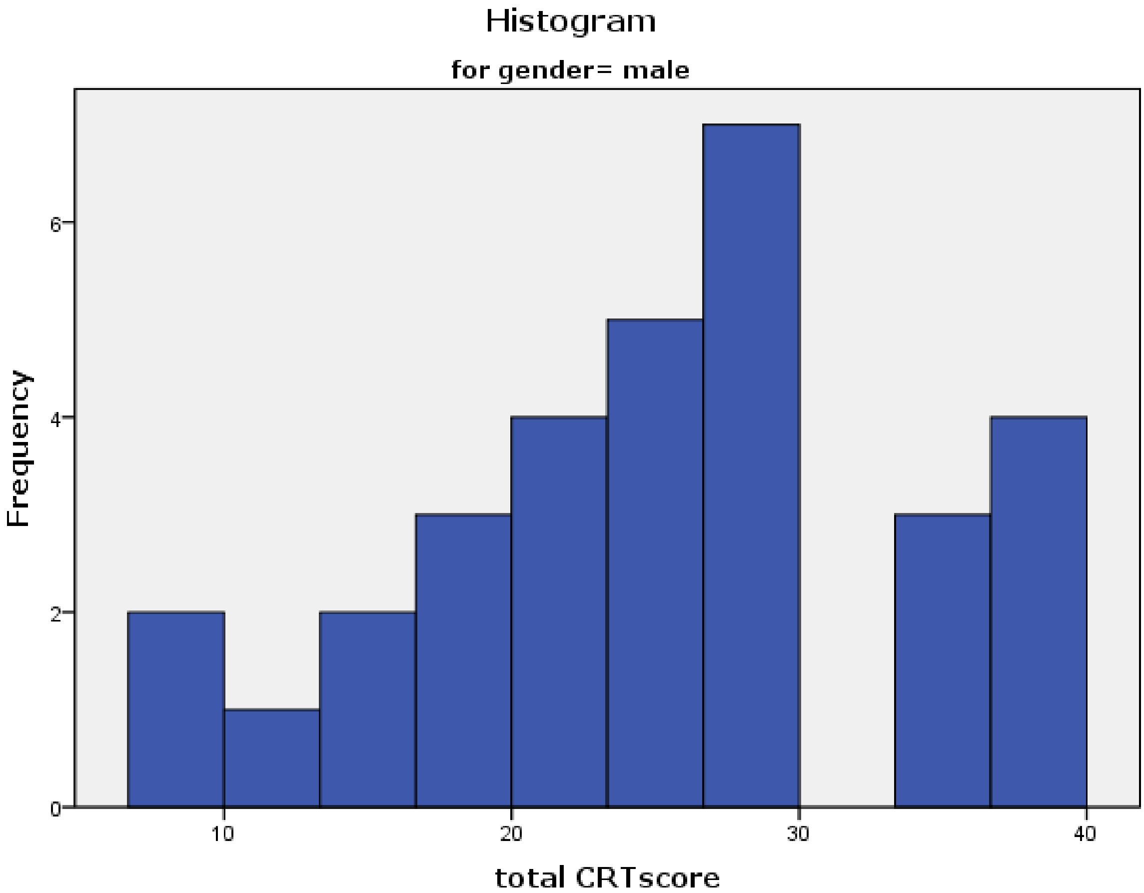

Figure 4:7: Histogram of the male student sample who took the final CRT showing non normal distribution of their test marks

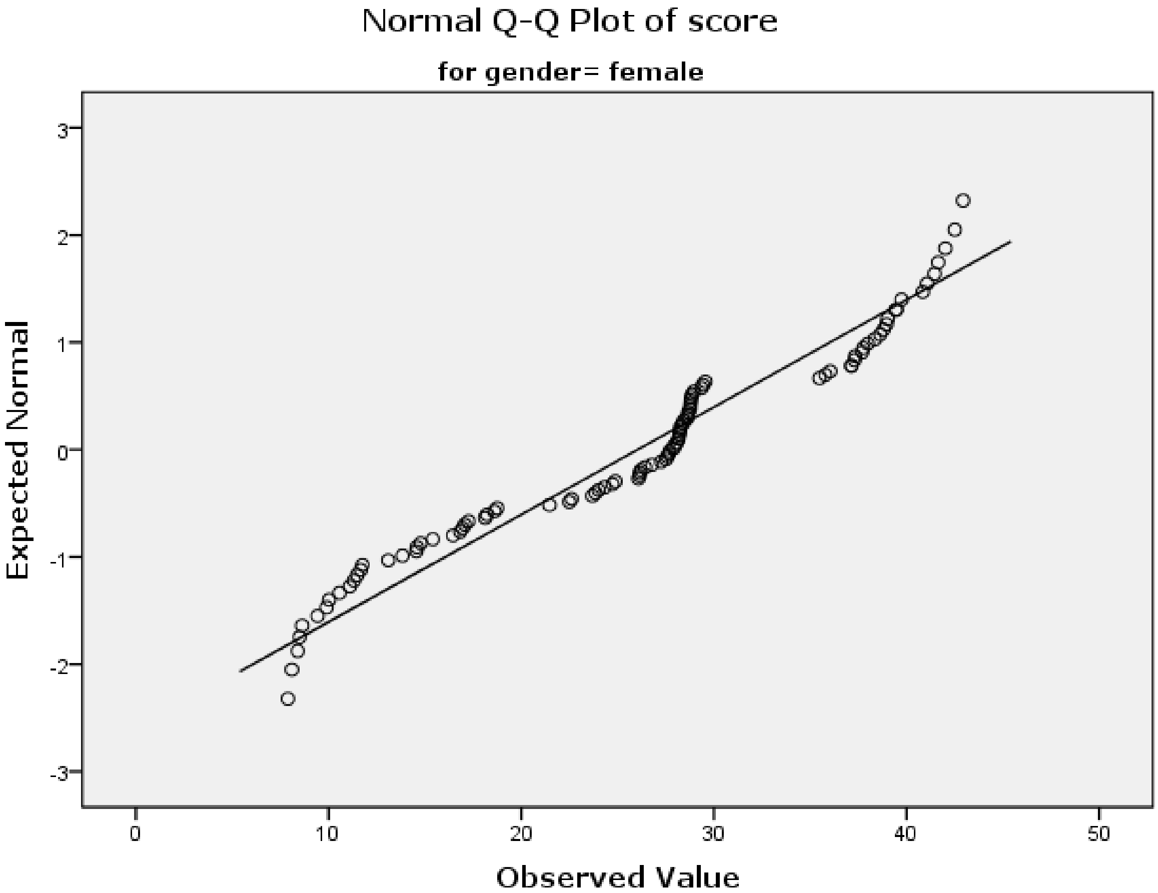

Figure 4:8: Normal Q-Q Plot of the female student sample who took the final CRT showing some data points away from the diagonal line

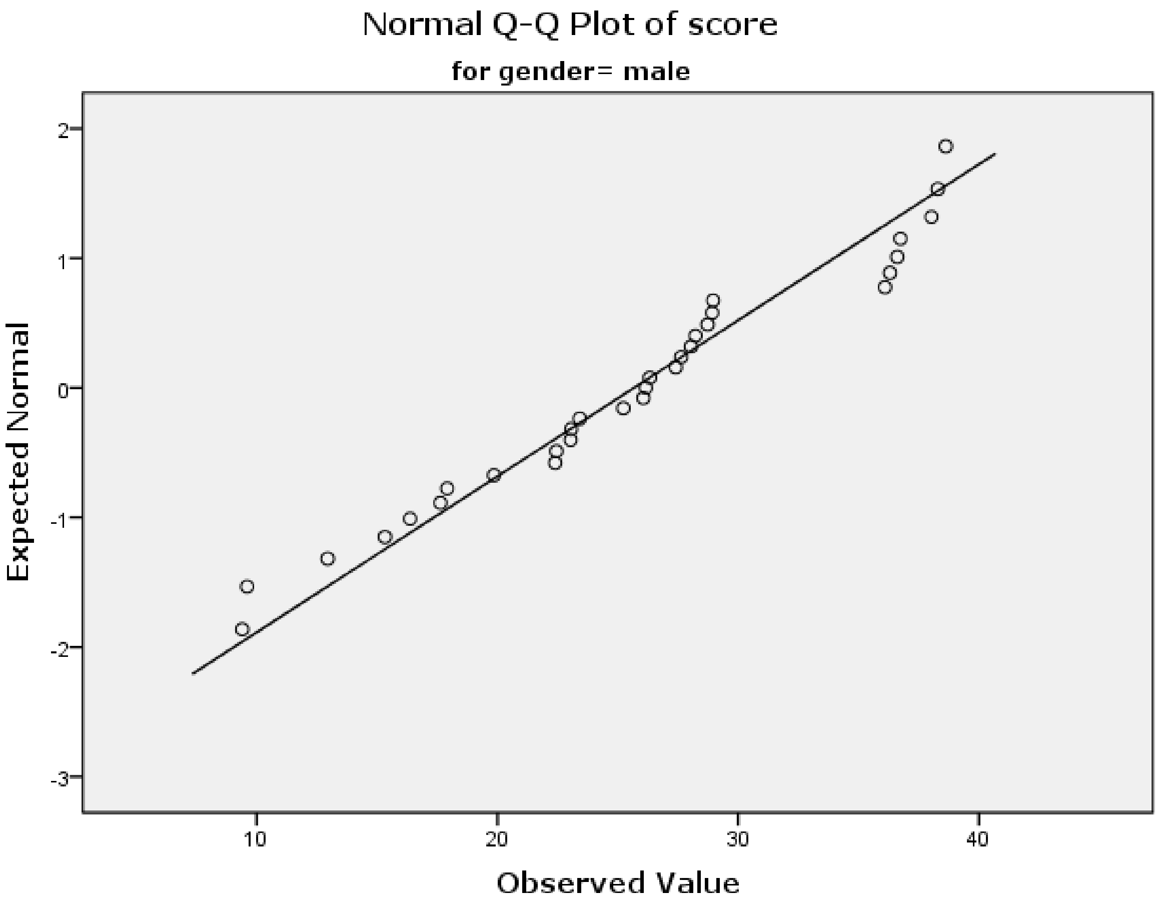

Figure 4:9: Normal Q-Q Plot of the male student sample who took the final CRT. Some data points were located away from the diagonal line

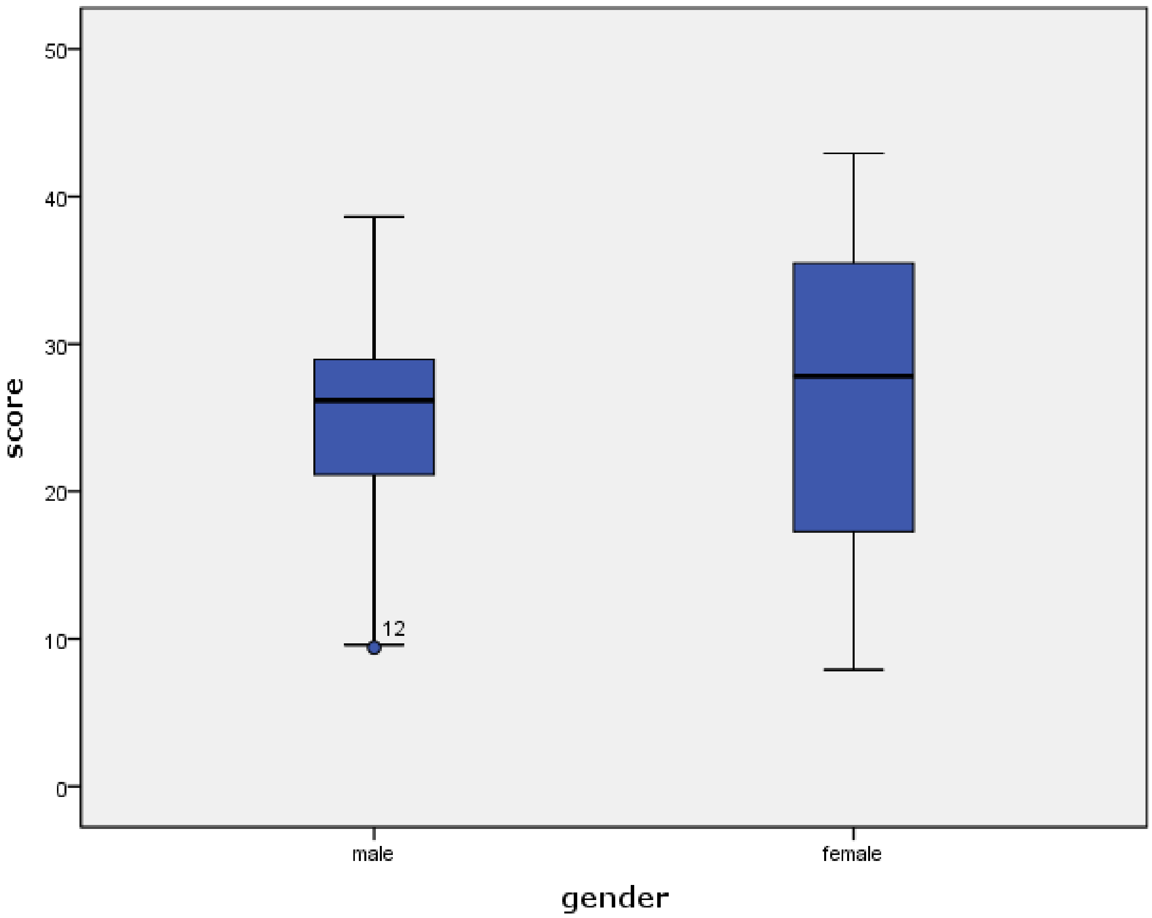

Figure 4:10: Box Plots for male and female student samples in the final testing phase. An outlier point appeared on one side of the box and the mean line did not lie near the central line of the boxplot in case of the male student sample

To calculate *z* value, we divided the values of Skewness and Kurtosis by their standard error. The values should be between -1.96 and 1.96 for normal distribution. For females it was -0.174/0.244= **-0.7131** and -0.926/0.483= **-1.9171** respectively. For the males' sample it was -0.156/0.421=**-0.371** and -0.571/0.821=**-0.695,** respectively.

The value of the Shapiro-Wilk Test was greater than 0.05, for males, but not for females. If it is below 0.05, the data significantly deviate from a normal distribution (Laerd Statistics, 2013).

By measuring the normality we found that some of our data were a little skewed and kurtotic *i.e.* our data were not normally distributed, in terms of skewness and kurtosis with regards to gender of the students' sample. Moreover, the visual inspection of histograms and Normal Q-Q Plots indicated that data deviated from the normal distribution regarding the different genders of the students' sample in the final testing phase.

4.4.2.4 Test of normality (Schools difference)

The same procedure was carried out for the students' sample to examine the normality status of our sample from the three different curriculum models.

Figure 4:11-Figure 4:17 present the visual aids of normality, (or non-normality), for the students' sample of the participating dental schools.

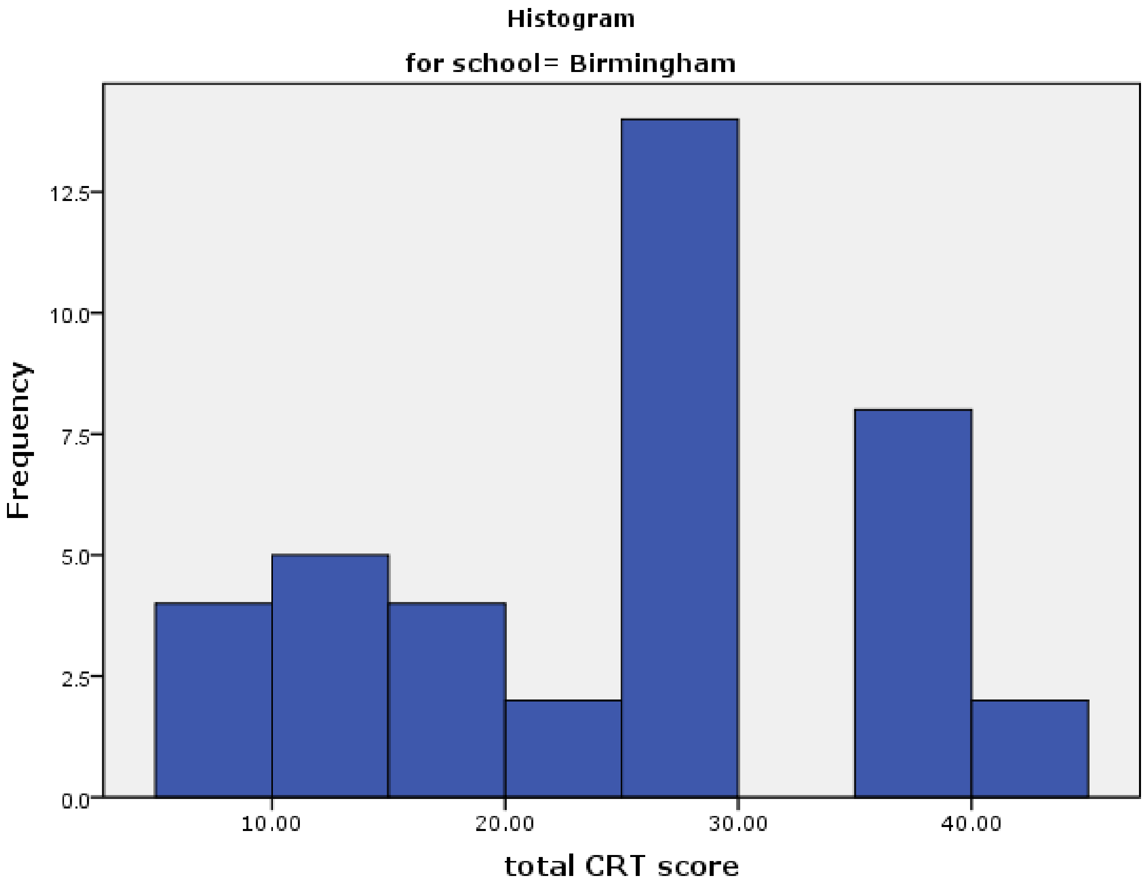

Figure 4:11: Histogram for Birmingham student sample showed non-normal distribution of the data

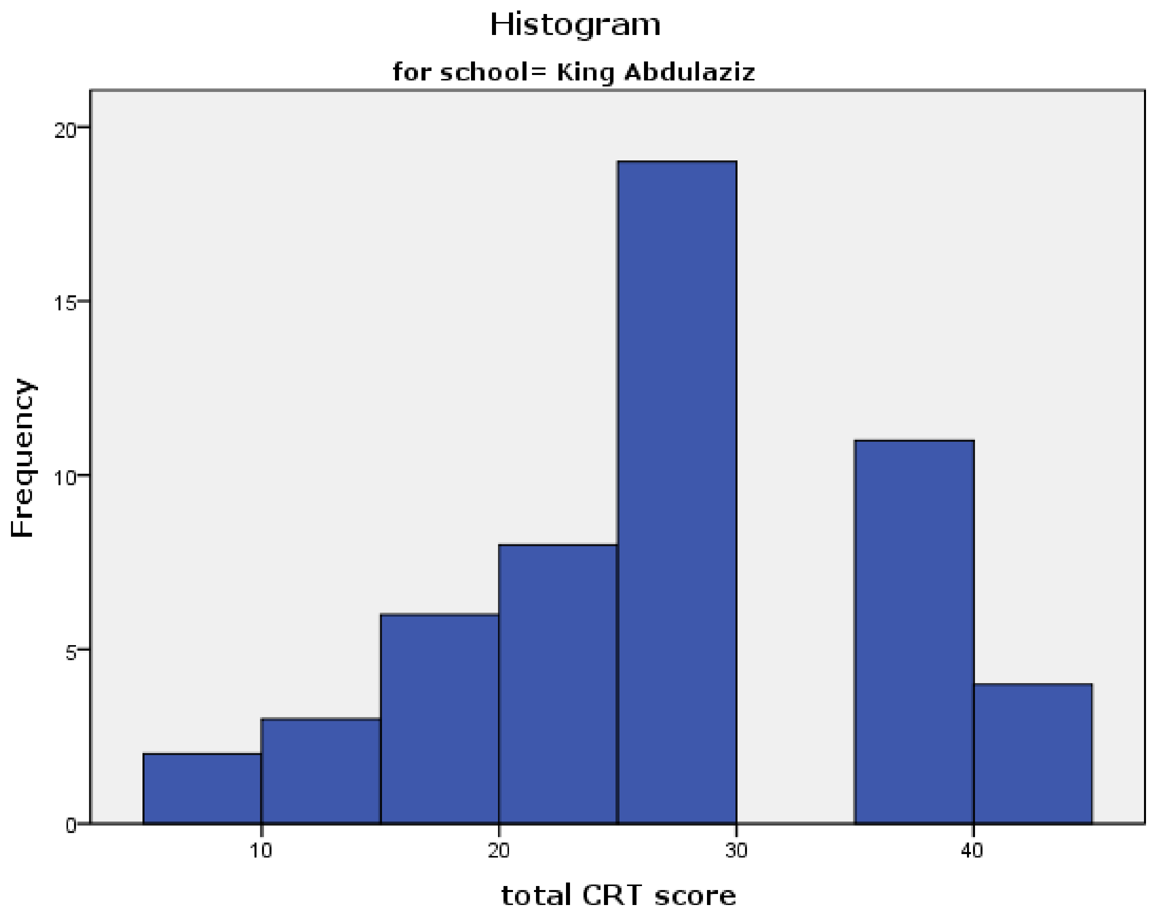

Figure 4:12: Histogram for King Abdulaziz student' sample reflecting non-normal distribution of the data

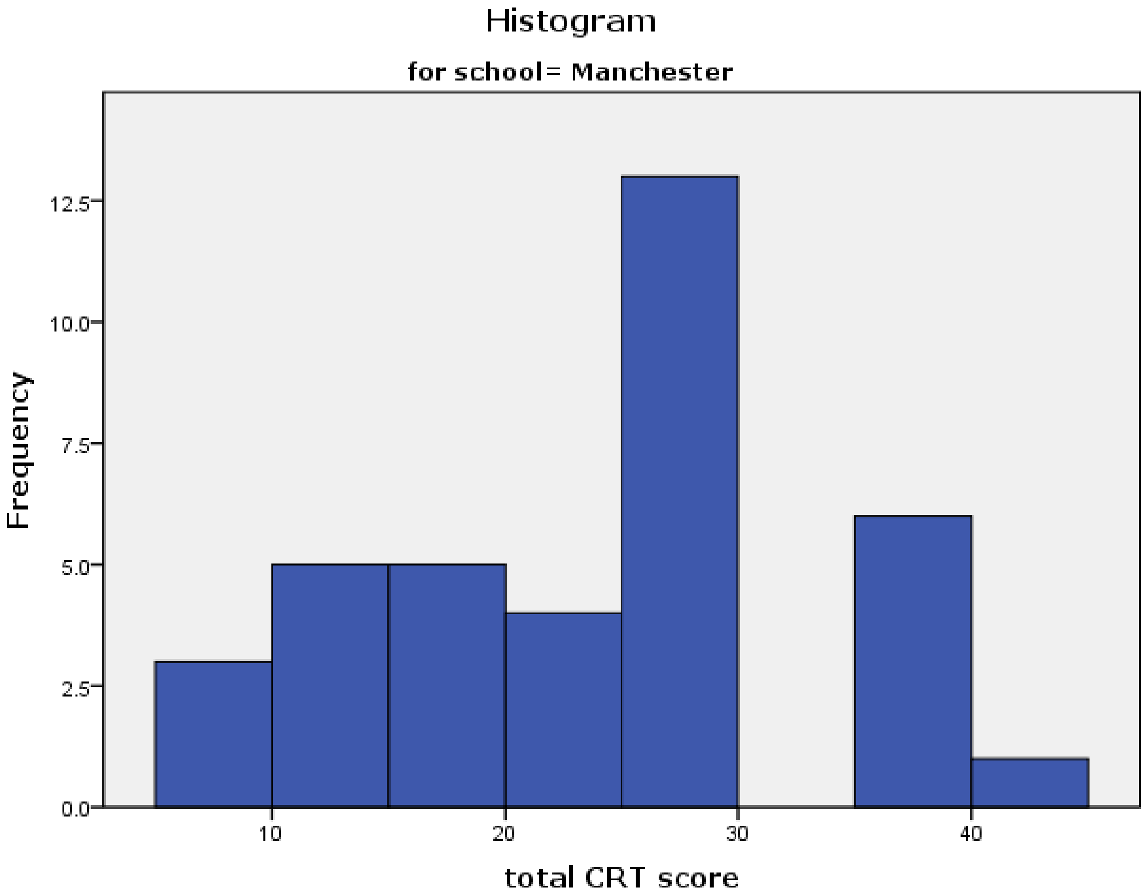

Figure 4:13: Histogram of Manchester student sample indicated skewed data

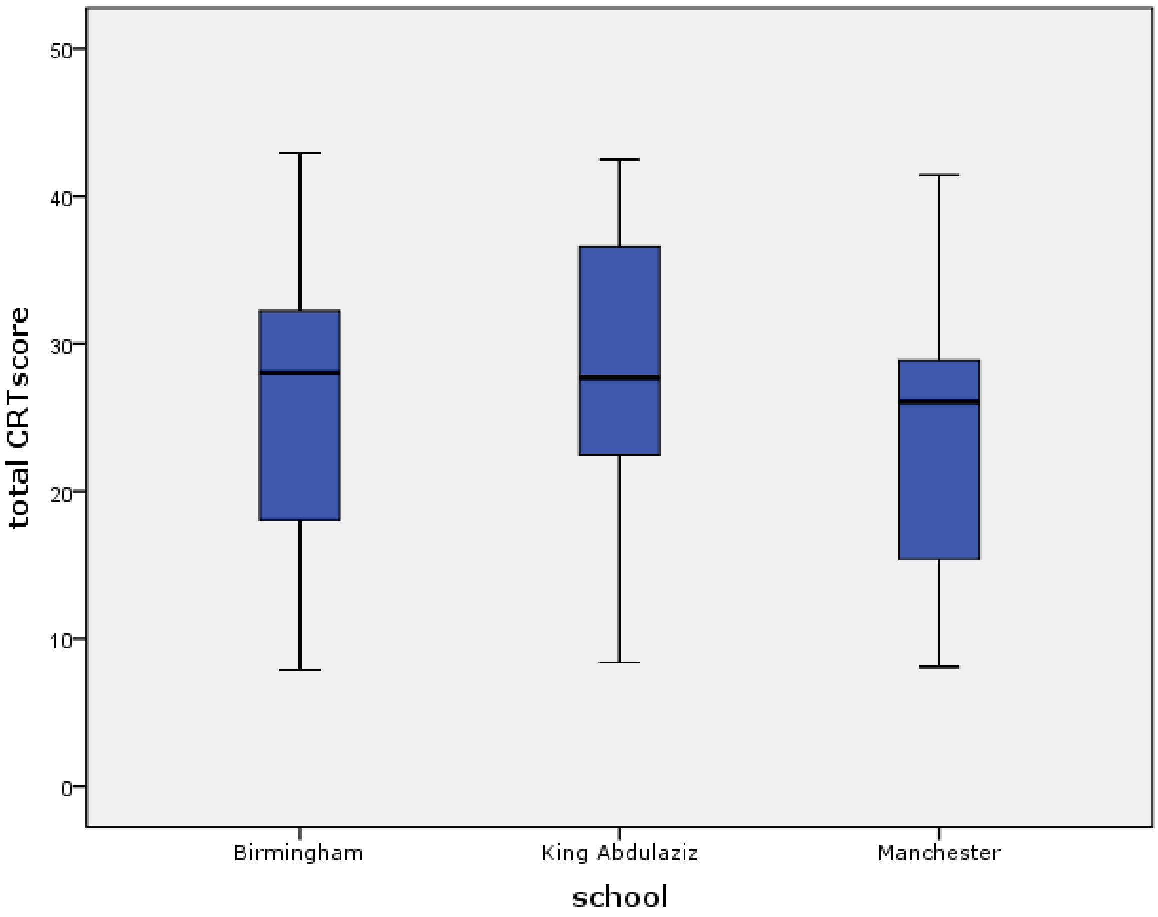

Figure 4:14: Box Plots for the three school samples illustrating that the mean values were not close to the centres of boxes, which indicate non-normal distribution of the data

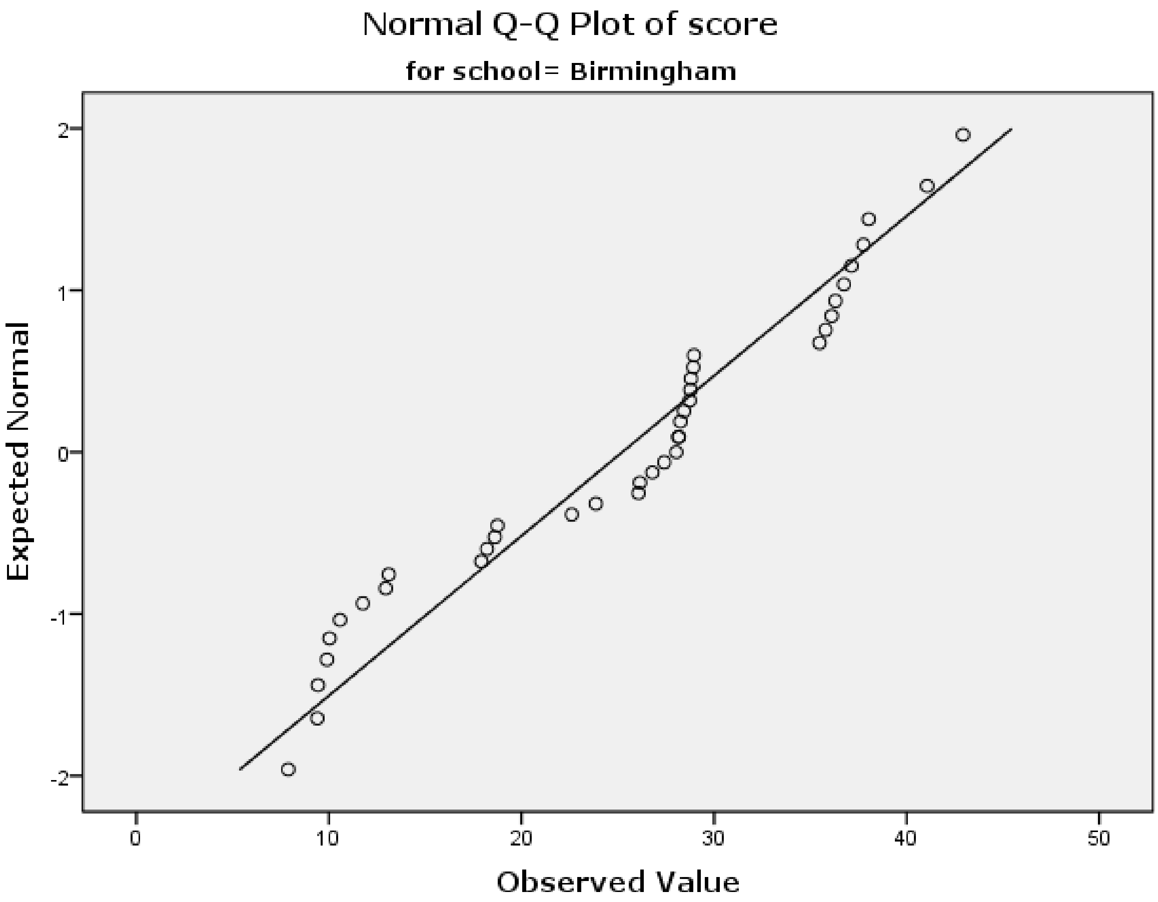

Figure 4:15: Normal Q-Q Plot for Birmingham student sample. Some data points were away from the diagonal line indicating non-normal distribution of the data

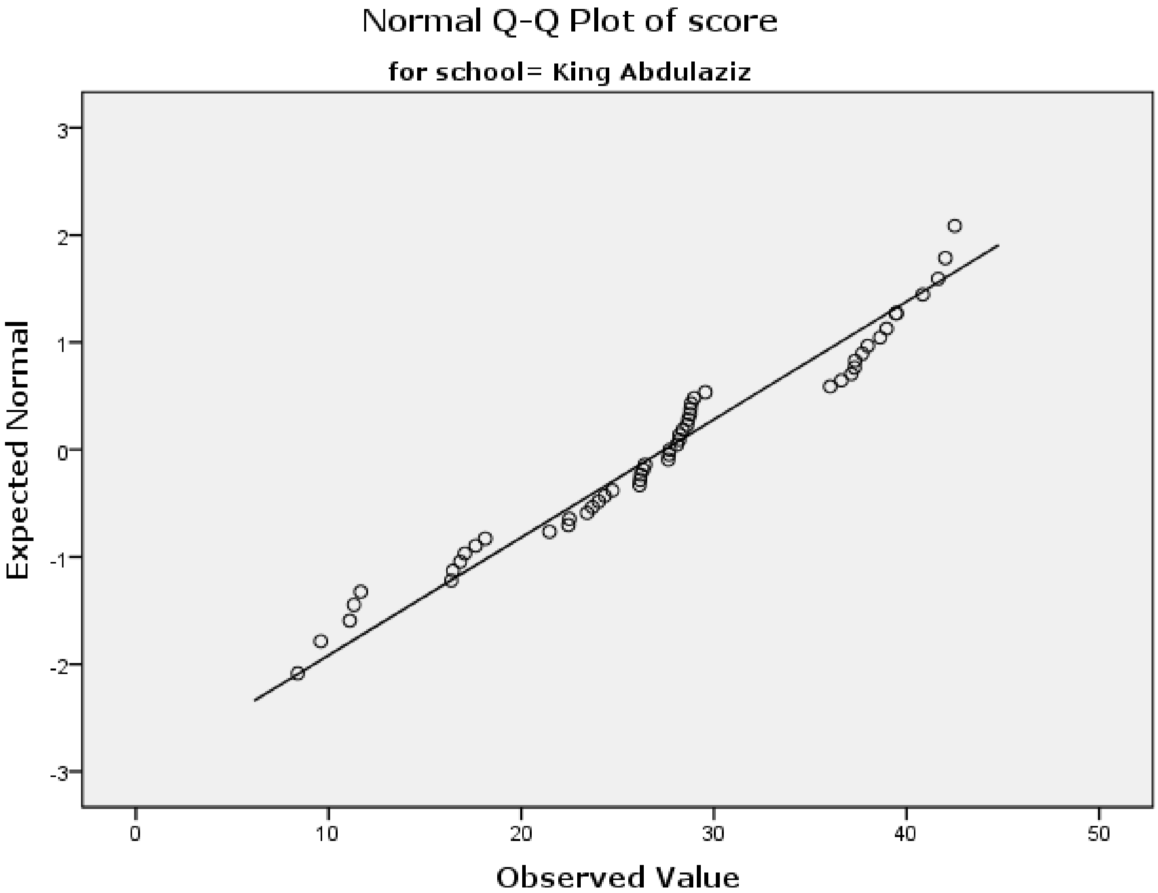

Figure 4:16: Normal Q-Q Plot for King Abdulaziz student' sample. Some of data points were located away from the diagonal line reflection non-normal distribution of the data

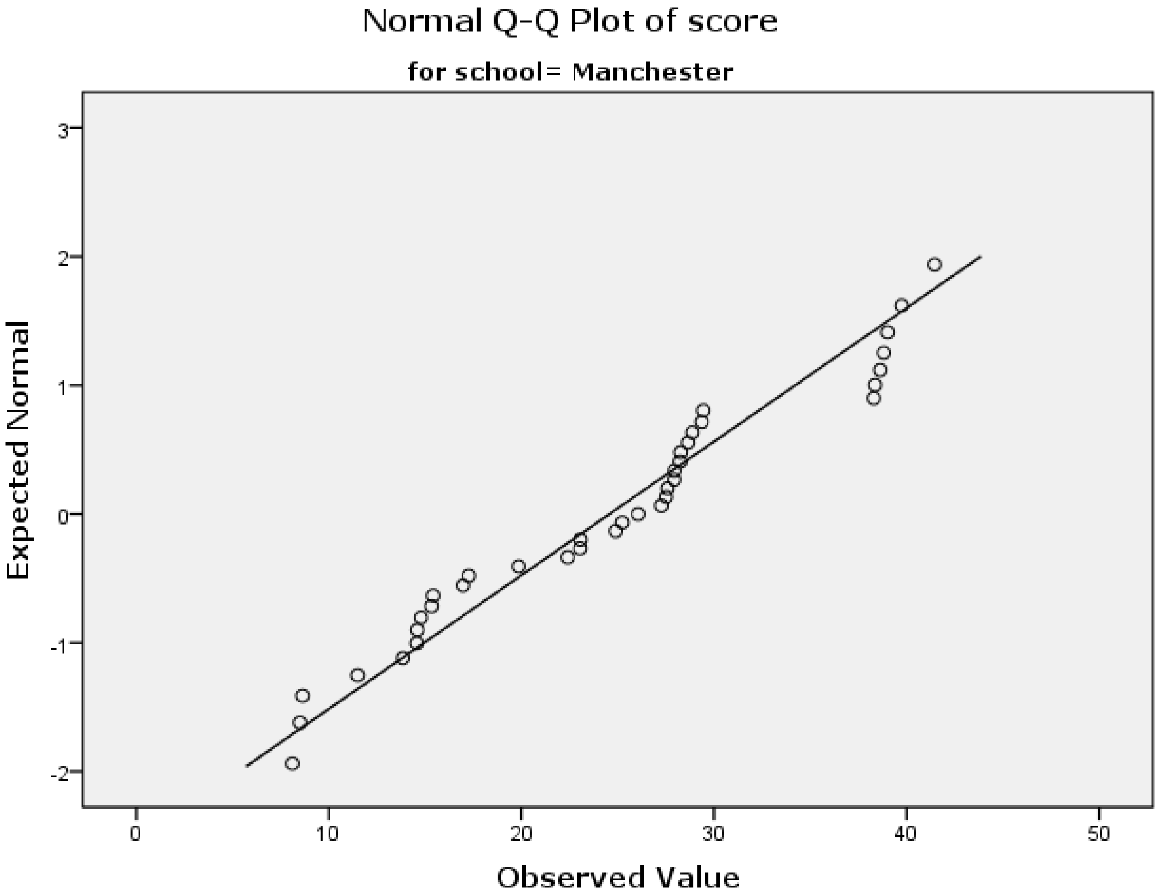

Figure 4:17: Normal Q-Q Plot for Manchester student sample. Some of the data points were away from the diagonal line reflecting a non-normal distribution

Z values were calculated for each school group using data, as follows:

- For Birmingham: -0.233/0.378=**-0.616**
  -1.019/0.741=**-1.375**
- For King Abdulaziz: -0.205/0.327=**-0.627**
  -0.609/0.644=**-0.946**
- For Manchester: 0.038/0.388=**0.0979**
  -0.866/0.759=**-1.141**

It was obvious that all of these values fell between -1.96 and 1.96. Shapiro-Wilk values were below 0.05 for both King Abdulaziz and Birmingham dental schools samples indicating the non-normal distribution of data for these two schools, while it showed normal distribution for Manchester dental school sample.

From the above presented data, we concluded that some data obtained from the students' sample, participating in the definitive phase of the study were not normally distributed. Therefore, non-parametric tests should be used to carry out statistical comparisons.

4.4.2.5 The relationship between students' gender and their performance in the CRT

In this section we will discuss the statistical procedures that were carried out to examine the relationship between the gender difference of the students' sample and their performance in the CRT presented by the total test marks as well as for each set of items separately. The mean values of the total test scores for both males and females were approximately similar being 25.67 and 26.04 respectively. However, the female sample showed a higher level of spread of the test score (standard deviation = 9.98) than the male sample (standard deviation = 8.31).

As discussed earlier, some of the data showed non normal distribution regarding normality of gender for the students' samples. In order to compare two independent variables (male & female), the best non-parametric test to compare the two groups is the Mann-Whitney U-test.

Table 4:8: Mann-Whitney U test showing no statistical difference between the male and female student samples in their total CRT marks in the final testing phase of the study

	score
Z	-0.59
Asymp. Sig. (2-tailed)	0.56

Since Table 4:8 shows that *P* >0.05, a conclusion to be made is that the data did not provide statistically significant evidences of a difference between males and females in their total CRT marks.

In order to obtain a detailed in-depth analysis of the possible difference between the male and female samples, analysis was also conducted for each category of the CRT items.

The categorisation of the CRT items based on the components of clinical reasoning they tested was presented in Table 4:2 on page 193. There was a significant difference between the two samples regarding their scores obtained for question 1. Question 1 was a KF item testing the selection of information, (see Table 4:1 &Table 4:2). For this question *p* value was 0.035 which is <0.05, indicating a significant difference between the two groups. In conclusion, there was no significant difference between the male and female samples in their marks obtained for individual test items except for question 1. The mean rank values for that question were 76.34 and 61.41 for the male and female samples respectively, indicated that males obtained better scores than females when they answered this particular question.

4.4.2.6 Comparison between the samples from the different schools taking the CRT

4.4.2.6.1 The total test mark

Table 4:9 indicates that on average students from King Abdulaziz University performed better than the other two cohorts (the mean value was 27.44). Birmingham and Manchester participants were nearly similar in their total test scores with mean values of 25.23 and 24.58, respectively. The spread of scores, as shown by the standard deviation values, was a little higher for Birmingham and

Manchester participants than it was for King Abdulaziz group. This was also reflected in the visual inspection of the Histograms and Box Plots, (see Figure 4:11-Figure 4:14).

Because data were continuous, non-normally distributed, and we intended to compare more than two independent groups, the non-parametric test, Kruskal Wallis was used (Laerd Statistics, 2013). The results of this test showed that there was no statistically significant difference between the CRT scores obtained by students from the three different schools (H (2) =1.835, *P*=0.4).

Table 4:9: Values of mean and standard deviation for the three cohorts of students participating in the final testing phase

School	N	Mean	Std. Deviation
Birmingham	39	25.23	10.12
King Abdulaziz	53	27.44	9.09
Manchester	37	24.58	9.63
Total	129	25.95	9.58

4.4.2.6.2 Differences between the three students' samples in the marks obtained from the different sets of test items (categories based on the components of clinical reasoning)

A decision was made to run separate non parametric tests to examine the possible difference in the scores for each test item category, (presented in Table 4:1). Scores were combined for each set of questions, and analysis was carried out in order to get a clearer view of the possible differences between the students' samples regarding answers to each category of the test items.

None of the *p* values were below 0.05 except for questions 6 and 17. This indicated that there was no significant difference between the three different dental schools regarding scores of items from the different categories, with the exception of two questions. These questions were Q6 and Q17.

Question 6 was a Key Feature type of clinical reasoning assessment. It also tested selection of information according to the suggested categories presented in (Table 4:1) on page192. Kruskal-Wallis H test showed that there was a statistically significant difference in scores for question 6 between the three different students' samples, p value =0.028. Mean rank values for question 6 were 62.50, 74.35 and 54.24 for Birmingham, King Abdulaziz and Manchester samples respectively. This indicated that students from King Abdulaziz dental school scored higher than students from the other two samples regarding question 6.

Furthermore, the Kruskal-Wallis H test also showed that there was a statistical difference in the scores for question 17 between the three cohorts of students coming from different schools, p=0.009, with a mean rank score 56.78 for Birmingham, 76.12 for King Abdulaziz, and 57.73 for Manchester samples. These results suggested that students from King Abdulaziz sample obtained higher scores than Birmingham and Manchester students' samples regarding question 17. This question was a PMP item testing hypothesis generation.

4.4.2.6.3 The different assessment tools

Because our CRT was a combination of three well-known assessment tools for clinical reasoning, a decision was made to combine the results of each type of question for each cohort of students and examine the differences between them.

Non-parametric tests were also carried out to analyse the possible differences between the three students' samples regarding the different test items whether they were KF, PMP or SCT items. Results of Kruskal-Wallis also showed that there were no statistically significant difference in the marks obtained from these different items, except for question 6 and 17, between the three students' samples.

4.4.2.7 The effect of the time spent for taking the test on the CRT marks

One of the advantages of the online test is that it is possible to measure the duration that each participant spent during the test. This section examines whether the test marks were affected by the length of time spent by the participants or not. Spent time was calculated for each group including expert dentists.

Figure 4:18 illustrates that the experts spent less time compared to the students' samples when taking the CRT. Figure 4:19 presents Box-Plots reflecting the time spent by male and female samples. It showed that the two samples nearly had the same time spending behaviour when taking the CRT.

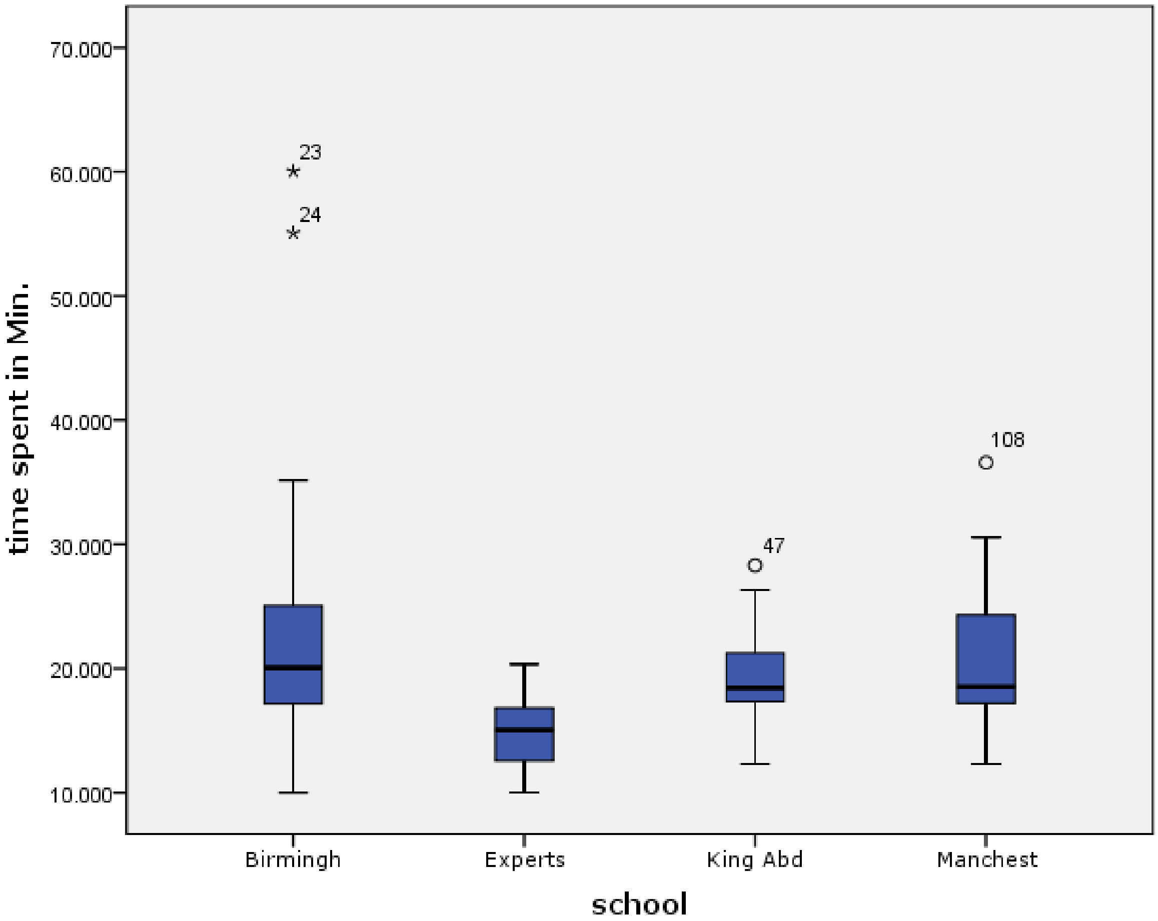

Figure 4:18: Box plots showing the time spent in minutes by all participating groups including experts. Experts spent less time when compared to the student cohorts when taking the final CRT

Table 4:10 illustrates the mean values of the length of time spent by each cohort during taking the final CRT. It shows that experts spent less time to answer the test when compared to students' sample.

Table 4:10: Mean values for the time spent by each cohort of participants when taking the CRT, showing that experts spent shorter time than students

group	N	Mean in min.	Std. Deviation
experts	16	14.93	2.86
Birmingham	39	22.42	10.29
King Abdulaziz	53	19.42	3.64
Manchester	37	20.94	5.66
Total	145	20.12	6.81

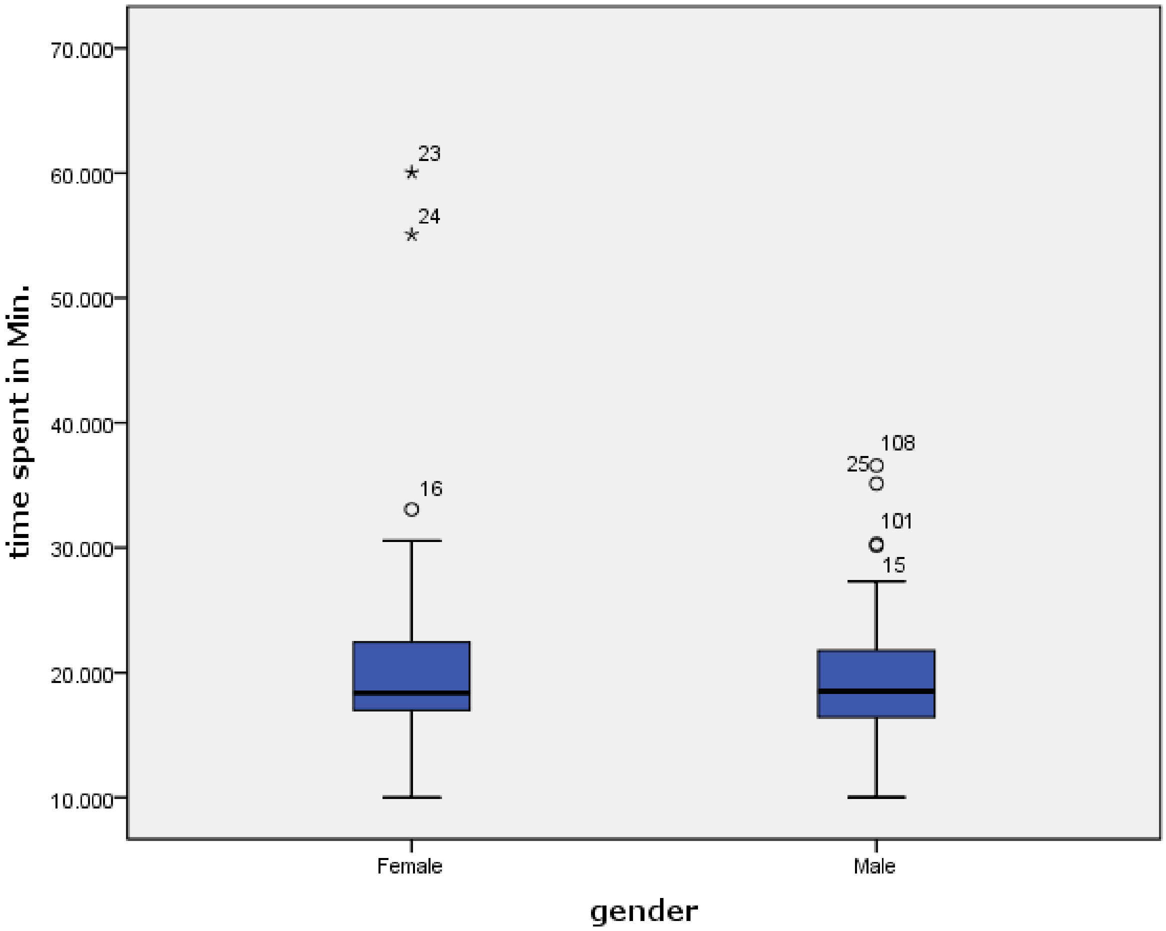

Figure 4:19: Box plots reflecting the time spent by the male and female student samples when taking the CRT. The mean values were relatively similar. Outliers may indicate spending of time searching for information by students when taking the CRT.

Pearson correlation coefficient, *r* was 0.18, and this is considered as a statistically weak correlation. It means that time spent by the students during the test was weakly positively correlated to the total test mark. This finding indicated that even if a student was spending time searching through text-books or the internet to look up answers for the test, it showed that this behaviour only had a minimal effect in increasing the total test mark.

4.4.2.8 Correlation between the knowledge and clinical reasoning

In order to understand the effect of knowledge on clinical reasoning we analysed the correlation of knowledge-based questions in the CRT (Q5 and Q25) and the total test marks obtained for the students' sample. Values of *r* were 0.61 for Q5 and 0.54 for Q25. Results of these correlation tests indicated that there was a strong positive correlation between the marks obtained from the knowledge testing items and the total CRT marks obtained by the students' sample.

4.4.2.9 Factor analysis

Factor analysis was carried out using SPSS software. It was found that nine components were identified. However, many of the test items were aggregated in one or two categories and many were classified in more than one factor. This could be explained by the fact that clinical reasoning is a mixture of more than one skill, and that the presented CRT is measuring one construct, *i.e.* clinical reasoning. Another explanation could be that the students were in their final year of their undergraduate study and they theoretically have acquired all the skills to become dentists. For that reason the CRT did not differentiate between the different skills required for clinical reasoning as the students' performance was comparatively similar.

4.4.2.10 Qualitative differences for question 22

As described earlier, question 22 was one of the items which discuss the psychosocial element of the CRT. One mark was allocated for this question. Participants who answered the question (any answer that can be analysed) were given one mark and zero for those who did not provide answers. This question asked the following:

"You offer endodontic treatment and crowns for multiple teeth and then do a removable partial denture. However, the patient tells you that he cannot afford the cost of this comprehensive treatment. He suggests that you extract his remaining teeth and do a complete denture. You also need to do a complete denture in order to finish your course requirements. What can you do in this case?"

In response to this question, about one third of the student participants left the answer box blank. Theoretically, they would then have attained zero marks for this question. Almost all the King Abdulaziz participants who answered the question suggested that the patient should be treated for free for his required comprehensive treatment rather than teeth clearing. Most of Manchester's and Birmingham's participants who answered the question expressed their need to take advice from a colleague or a clinical instructor after trying to convince the patient about the need to go through the comprehensive process of root canal treatment and crowns together with the fabrication of a partial denture *e.g.*

"I'll try to explain to the patient that it is so bad to lose a restorable tooth…I won't do it myself. I'd rather refer him"

However, a very small number of participants, two from King Abdulaziz and one from Birmingham, answered that they would do what the patient wanted, as long as he was aware of the available options.

4.5 Discussion

Traditionally, it has been suggested that diagnostic accuracy was a function of sound knowledge (Boshuizen and Schmidt, 2008). Therefore, assessment of clinical reasoning was mainly conducted through assessing knowledge base information. However, this assumption can be challenged by the fact that there are obviously other factors affecting the development of CR and the accuracy of this type of assessment. The basic skills of clinical reasoning were commonly assessed through ward rounds, viva examination and practice attachments. These tools are generally unstructured and informal with low standardisation levels. Moreover, they may be biased in case selection, be subjective and lack inter-rater reliability (Newble et al., 2000). Furthermore, these measures assess only the outcome *i.e.* the end product of clinical reasoning (diagnosis and management) rather than the process itself (Groves et al., 2002).

We support the argument made by Neufeld *et al* (1981), who suggested that problem-solving ability is not a single skill that could be assessed separately from other competencies which include knowledge application, selection of data in order to generate hypotheses and evaluating the need for more data, history taking and physical examination techniques, and communication skills. Following developments in clinical reasoning research there was a concurrent development of the tools for its assessment with different levels of validity and reliability. The clinical reasoning test presented in this study aimed to mix more than one type of the well-known assessment tools used in the literature. The intention was to add the advantages of these tools in one high quality test of clinical reasoning. The developed CRT has been shown to have acceptable levels of validity and reliability.

Different items of the test examined different components of the clinical reasoning process such as selection of information, hypotheses generation, testing of hypotheses, providing management options as well as a few knowledge-based questions.

The test was also able to statistically differentiate between students and expert dentists. Furthermore, it was able to evaluate the interaction between subjects and test items following the concepts of IRT.

Despite the significant difference between the male and female students' samples regarding only one item of the CRT, which was a KF tested selection of information, the results of the current study showed that there was no statistically significant gender-related difference in the total test marks. This result was consistent with many other studies which indicated that there is no relationship between gender and the level of clinical reasoning ability (Anderson, 2006, Ashoorion et al., 2012, Da Silva, 2013, Hong Kong Polythechnic University, 2014, Shafaroodi et al., 2014). Beside its passive effect in case of dental and medical students, it was also been found that gender difference do not affect the treatment decisions made by dentists and these decisions are made irrespective of gender. However, male dentists tend to perform complex therapies themselves, whereas female dentists referred more patients to specialist (Zitzmann et al., 2011).

In contrast, the results of Groves *et al* (2003a) study suggested that female gender was a positive predictor of the clinical reasoning ability. However, this was approved only for only one type of clinical reasoning assessment namely *the clinical reasoning problems (CRP)* and not in case of another type of clinical reasoning assessment; *Diagnostic Thinking Inventory (DTI)*. The explanation given by the authors was that female students tend to be more careful and thorough in their approach to diagnosis as they can identify all critical features from a case presentation, in the case of a CRP, (indicated by DTI).

Although the mean value of the total test mark was slightly higher for the King Abdulaziz sample than that of the other two cohorts, statistical comparison between the three samples supported the null hypothesis in that there was no significant difference between the different cohorts. This finding showed that there was no statistical difference between the samples despite the cultural and geographical differences. This result agrees with what is argued about the effect of the different curricula on the development of clinical reasoning skills in medical students in the literature. It was suggested that although there are significant differences in the clinical reasoning ability of medical students in favour of the PBL program over the students from traditional curriculum, this difference diminishes when students proceed to the last years of their study, suggesting that towards graduation there is no differences in reasoning ability based on the type of undergraduate curriculum (Da Silva, 2013, Groves et al., 2003a).

In order to explain our results, we suggest that this is a reflection of the fact that our study targeted the students when they were in their final year of undergraduate dental course. It is not unusual for the students at this stage to perform similarly, as they have already acquired all the basics to become dentists. However, they were still lacking the element of experience as reflected in the statistical difference of the performance between the students and experts dentists.

Despite the fact that there was no statistically significant difference in the total CRT marks between students regarding their different curricula, analysis of individual CRT items according to their classification (based on their type of assessment) revealed different results. These results suggested that there was a statistically significant difference between the three groups of students with regard to two questions. These two questions were a KF and a PMP. We may relate this finding to the relatively higher number of participants in case of King Abdulaziz School compared to the other two groups (53 participants from King Abdulaziz, 39 from Birmingham and 37 from Manchester). The law of large number implies that in smaller samples there is a higher likelihood of having cases that do not conform with the norms (being either much better or much worse) which can affect the comparison (Durrett, 2010).

Many studies showed that expert dentists perform better than dental students (Crespo et al., 2004, Dasari, 2006, Simmons, 2010). The results of the current study showed that experts performed better and spent less time answering the CRT compared to the students' samples. This finding was consistent with what is published in the literature as experts usually spend less time to reason through clinical cases than novices (Hong Kong Polythechnic University, 2014, Smith et al., 2010).

The results also showed that despite the small number of the knowledge-based questions, there was a strong positive correlation of results obtained for these questions with the total test marks obtained by the students' sample. This finding supports what was argued in the literature about the importance of knowledge in clinical reasoning skills development (Boshuizen and Schmidt, 1990, Eva, 2005, Norman, 2005, Rikers et al., 2004, Schmidt et al., 1990).

Analysis of question 22 showed that about third of the participants did not provide answers to this particular question. The reason behind their response could be due to the fact that they may feel uncomfortable in answering this question and the ethical dilemma being difficult for the students to take a decision especially as they were taking the CRT as volunteers, *i.e.* there was no need to answer all questions as if they were dealing with a summative exam. Qualitative analysis of the participants' answers to this question revealed that most of the students who answered this question conform to the ethical guidelines of dental care. This supports the results of Khatami (2010) who found that ethical reasoning is common in dental students, see Chapter 2 for details.

Despite the small number of participating students who preferred going with the patient's preference of extracting all of his teeth, including the restorable ones, when answering question 22, their response could be related to the curriculum models at their schools. Dental schools at Birmingham and King Abdulaziz universities are both requirement-based types of curricula. Students are required to complete certain amount of dental procedures in order to pass specific years of their undergraduate course. The University of Manchester, however, implements a competency-based system.

Students' decisions on the possible management options for the patient also reflected the difference in health systems applied in these two different countries. Participants at KAU suggested that the patient should be provided with the best treatment free of charge, and the inability of the patient to afford the treatment should not be considered as a problem to compromise the best option. Dental care is offered free of charge for all patients in SA. On the other hand, participants from the UK actually considered this as a factor that may affect the choice of the treatment options as the NHS sets special criteria for free dental care in the UK.

The results of the factor analysis showed that although nine components were identified, many of the test items were correlated to one or two categories and many were classified in more than one factor. We suggest that this could simply reflect the fact that clinical reasoning is a mixture of more than one skill, and that the CRT measured clinical reasoning as a single construct.

4.6 Limitations

Curriculum comparisons can be conducted through the assessment of students' performance. However, comparing single test results from different cohorts of students at different schools may not be sufficiently reliable because of the psychometric sources of errors generated by group and cohort effects which could limit the generalizability of findings (Muijtjens et al., 2008). Differences in students' admission strategies, the hidden effect of the different curricula (mentioned in Chapter 3) and cultural effects are matters which further complicate the problem. To overcome this drawback of the single test comparison Muijtjens *et al* (2007) found that longitudinal benchmarking[5] is better than the cross-sectional comparison especially in case of non-homogeneity of the schools being compared.

Berliner (2002) concluded that effects of a specific program can never be consistent at different sites. This is because every local context is different in its requirements for programs, personnel, teaching methods, budgets, leadership and characteristics of community support. Students' gain of knowledge is also affected by differences in teachers (Rivkin et al., 2005), and the interpersonal relationships between faculty and students (Hafferty, 1998).

' when a researcher claims that " such and such an effect " is true, other things being equal, he speaks from the experience of having set a great many other things equal' Donald Campbell

[5] Benchmarking is an ongoing, systematic process for measuring and comparing the work processes of one organization to those of another, by bringing an external focus to internal activities, functions, or operations KEMPNER, D. E. 1993. The pilot years: the growth of the NACUBO benchmarking project. *NACUBO Business Officer,* 27**,** 21-31.

Another issue was the possibility of origin bias of test items in favour of the school were test items were produced. Muijtjens *et al* (2007) found that students obtained better test results on the test items produced at their own school in a cross-sectional comparative study. However, this bias affects students mainly in their middle years of the undergraduate study, and has a minimal effect on the first and final year students. Although, the results were concurrent with many studies in the literature, they cannot be generalised because of the relatively small sample size. The low sample size used in this study could also affect the results in that it did not provide enough data for the comparison.

Online testing has the disadvantages of possible browsing and searching for the required information to answer the test, especially for the knowledge based questions. However, the CRT was a case-based test with each case being especially created for the purpose of the test and not copied from other sources. If we suggest that those participants who spent long time taking the CRT were looking for materials to help in answering the questions, the results indicated that time spent to answer CRT has no effect on the total test mark. In other words, even if students looked for materials to help in answering the questions, this showed no effect on their marks.

Although the test was created in a unidirectional format, participants were able to view the test at first and have another go when they are familiar with its contents. A few cases, nine participants, were found to do this identified by their computer ID being registered more than one time. However, we cannot guarantee that the test was taken by the same person because they can simply use the same compute located at their study site. That is another disadvantage of online surveys. Moreover, a few students took a very long time answering the test.

4.7 Conclusion

In this study the main aim was to develop a high quality assessment tool for clinical reasoning in order to address the need in the literature for the development of a good assessment tool for clinical reasoning. The developed CRT was a mixture of different assessment tools including different types of dental cases presenting most of the dental subjects taught during BDS courses. It also tackled psychosocial and ethical issues as they should be considered during decision making. Visual triggers were included in almost all the cases presented in the CRT because pattern recognition is a commonly known strategy of clinical reasoning for dental students.

This test was shown to be both valid and reliable. One of the special features of this test is that it is considered to be relatively short compared to the other well-known tools in the literature. Furthermore, it was developed as a mixture of more than one type of tool used for measuring clinical reasoning. The mixture is thought to combine the advantages of these tools. In addition, this test was novel in that it considered the interaction between test items and the subjects during the pilot phase using IRT. Improvement was carried out in order to get better item-student interaction. Every attempt should be made to develop an assessment tool which matches the ability of the students to be assessed. When this was taken into consideration, a better validity and reliability were obtained. CRT also assessed both the process (represented by the SC questions) and the end product of clinical reasoning (represented by the KF questions). The test questions were varied in their aim and covered as most of the components of clinical reasoning.

The results showed that CRT differentiated between experts and students. This difference was important in that it supported what is agreed upon in the literature as experts have better clinical reasoning skills than students. The difference also stresses the importance of experience in the development of these skills. Therefore, frequent exposure of students to multiple different dental cases is recommended.

No statistically significant differences were found between the results of students from different curriculum models or different gender. This could be caused by the samples' characteristics *i.e.* final year dental students. We conclude that at the time of graduation from undergraduate dental courses, students showed similar clinical reasoning abilities despite the differences in curriculum models.

Based on the qualitative analysis of question 22, it can be concluded that dental students usually follow the ritual and ethical principles of dentistry when making a treatment decision. However, requirement-based type of curriculum could sometimes put the students under the pressure of trying to complete their requirements even if it deviates from the ideal situation of treatment. A competency-based curriculum, however, relieves this stress on the students.

5 Chapter 5: Clinical reasoning in dental students: a qualitative study

Chapter outline

In order to complement the quantitative comparative study presented in the previous chapter a thematic analysis of transcribed in-depth interviews was carried out to get an in-depth understanding of what clinical reasoning means to an accessible sample of final year dental students. These semi-structured individual interviews were conducted with eighteen final year dental students from three dental schools implementing different curriculum models. Themes were identified to characterise the processes and the strategies used by dental students when they attempted to deal with clinical vignettes. Differences between the samples were also identified and will be discussed later. Before presenting the qualitative study, a brief background on qualitative research will be presented.

This chapter has the following structure:

- Background on qualitative research in medicine
- Understanding what clinical reasoning means from a group of final year dental students' point of view
- Comparing similarities and differences in interpreting clinical reasoning among this group of students, who came from different dental schools using different curricula.
- Comparing the processes and strategies of clinical reasoning in this group of dental students

5.1 Background on qualitative research in medicine

5.1.1 History and nature of qualitative research

Different research paradigms were briefly mentioned in Chapter 1. However, a more detailed description will be provided here. Two major theoretical approaches or paradigms have been identified to guide research. The first approach is *Positivism,* a term first coined by Comte in the 1830s (Durning et al., 2011). For Comte the word positivism was synonymous with science or empirical (positive) facts and is associated with the scientific method and quantitative research methodologies (Maykut and Morehouse, 1994). The second approach is known as *Phenomenology*. As defined by Patton this is the approach which focuses on the subjective meaning events have for persons being studied (Durning and Artino, 2001). This approach includes qualitative research, ethnomethodology, symbolic interactionism, hermeneutic inquiry, grounded theory, naturalist inquiry, and ethnography.

Positivism or the scientific (quantitative) approach has been the dominant paradigm of research in medicine. In this case the researcher applies an established theory, formulates suggestions and examines the results to support or refute his/her hypotheses. On the other hand, the qualitative approach deals with the researcher's and the participant's interpretations of a subjective phenomenon or experience. Durning *et al* (2011) referred to the difference between qualitative and quantitative researchers, as follows:

'*The qualitative researcher seeks patterns which come out of or emerge from the data. The quantitative researcher makes a guess or forms a hypothesis which is then used to test the data*'.

Pope and Mays concluded that it is difficult to provide a suitable definition for qualitative research as it is considered a field of inquiry on its own, crosscutting, multi-disciplinary, fields and subject matters with different interpretations related to the researchers' view (Maykut and Morehouse, 1994, Denzin and Lincoln, 2000). However, some definitions are found for qualitative research one of which describes it as 'a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible' (Denzin and Lincoln, 2000). Qualitative research can be referred to as interpretive research because it is concerned with how people interpret their experiences and social phenomena (Pope and Mays, 2006).

Qualitative studies started in cultural anthropology. The history of qualitative research began with studying groups of people who were considered as being marginal to society such as 'primitive' humans, or neurotic women and children. For that reason this type of research did not gain much attention as serious research until William Perry studied a group of Harvard males in 1970 (Maykut and Morehouse, 1994).

The weak influence of qualitative research was also reflected in medicine, as this type of research was commonly presented in a way that did not challenge the language of the dominating scientific tradition. The work of Sigmund Freud is an early example of qualitative research in medicine. He was a medical doctor who presented his case studies to build his theory in a medical context in a way that resembled the positivist approach rather than gaining information from careful examination of his case studies with more focus on his subjective analysis. Furthermore, transcripts of his therapy were not published and made available for public inspection until Rogers presented his work in 1942 (*ibid*).

The work of many important qualitative researchers such as Piaget and Ainsworth (Piaget, 1999, Ainsworth and de Jonge, 2010), did not describe their methodology for other researchers to copy. Instead, one was left uncertain about how the researchers reached their conclusions.

Qualitative methods of research have faced challenges to this day because the philosophical underpinnings were not widely understood or well defined (Pope and Mays, 2006, Durning and Artino, 2001). Even in some recent research, the methodological information, data collection, analysis and conclusions are vague for the reader, with little explanation provided by the authors. This lack of clarity in the research method may have also contributed to less attention being given to qualitative research in contrast to well-defined quantitative research.

In the interpretive approach researchers disagree with the positivist model which asserts that scientific enquiry is 'value free'. They see this view as an ideal scientific research by nature is a social process in which one cannot separate the effect of the social context on the study itself. The other argument is that 'value free' enquiry is morally unacceptable and that science should not stand outside society (Green and Thorogood, 2009).

Some characteristics associated with qualitative research include the following:

- An exploratory and descriptive focus: qualitative research tends to study human criteria and thoughts with more in depth explanation and rich description. It usually starts with questioning about the nature and characteristics of a phenomenon focussing on meaning and understanding. The end product of qualitative studies includes detailed descriptions and analysis of data with more writings included compared to quantitative studies.

- Emergent design: the researcher usually is led by the results of data. The researcher can modify and alter his/her action during data collection in response to the analysis carried out for the collected data. However, non-emergent research design could also be employed in qualitative research. In this case data collection is completed before they can be analysed. In this case the research is less open and responsive, but can still lead to important findings.
- A purposive sample: participants are carefully selected in a way that increases the variability of the sample and best answer the research questions, although the results are not usually generalizable.
- Data collection in context: qualitative research is interested in studying participants' experience in natural settings. The researcher often goes to the places of interest and interviews or observes participants.
- Emphasis on '*human-as-instrument'*: the researcher acts as data collector and selector of the relevant data and caller of meaning emerging from data. Data is often described in the participants' own words. However, data interpretation could still reflect the specific stance and thoughts of the researcher.
- Qualitative methods of data collection: in qualitative research data comes from participants' words or actions through the use of certain ways, including observation, interviews, and documents analysis.
- Early and ingoing inductive data analysis: focus of the research inquiry could be actively changed, broaden, narrowed or altered during the phase of data collection.
- A case study approach to reporting research outcomes: the results of the qualitative research are commonly presented by a rich narrative.
- High tolerance for ambiguity: qualitative research has a flexible design. Many variables are not known before conducting data analysis. Analysis of data gradually clarifies these variables.

Adapted from: (Denzin and Lincoln, 2000, Merriam, 2009, Darlington and Scott, 2002)

As mentioned earlier, more than ten years ago, qualitative research was described in health research as being unscientific due to the lack of a clear understanding of its nature, definition and implementation (Pope and Mays, 2006). However, nowadays, quantitative and qualitative methods are being increasingly used together in a mixed method approach in health care research. The use of mixed methods has proved to have a positive effect on heath research. Qualitative methods are claimed to add a deeper understanding and can provide potentially rigorous and methodologically sound study designs which supports quantitative research (DiCicco-Bloom and Crabtree, 2006).

5.1.2 Approaches to qualitative research

There are multiple approaches to qualitative research which guide the process of data collection and analysis. These approaches include discourse analysis, ethnography and the most important to the current research the **descriptive-interpretive** approach. In this section we will discuss the descriptive-interpretive approach in particular rather than the other types which are beyond the scope of this research.

There are some common variations to the interpretive approach including grounded theory, empirical phenomenology, hermeneutic-interpretive research, interpretive phenomenological analysis and consensual qualitative research (Elliott and Timulak, 2005).

As stated by Smith (1992), interpretive approaches to research involve interpretation of any form of human expressions including written, verbal or physical types of expressions. These expressions reflect knowledge, experience, reason, interest, intention, and motivation of individuals and are embedded in the interactions of the individuals with a broader historical and social context. Research question in the interpretive approach could be aiming to: define a phenomena, in this case it can be referred to as *definitional*; *descriptive*, in which the researcher describes kinds or variations of the phenomena under study; *interpretive*, in this case the question is directed towards the causes that lead to the emerging of the phenomenon and how it is affected by other factors; *critical/action*, concerning with what is right and wrong about the phenomenon and how it could be improved; and finally, *deconstruction*, discussing the social; and political interests serving the assumptions emerging from the research (Elliott and Timulak, 2005).

5.1.3 Research design in qualitative research

Research design could be *emergent* in which the researcher begins with initial focus and an initial sample. Then during data collection and analysis this initial focus could be refined and more data needs to be collected. In contrast, the *non-emergent* means that the researcher adopts the qualitative methods of data collection and data analysis, but data collection is completed before data analysis.

5.1.4 Conducting a literature review in qualitative research

There is a controversy regarding the timing of carrying out a literature review in qualitative studies. On the one hand, some qualitative researchers prefer that the researcher should not conduct a literature review before data collection. This was suggested to minimise the effect of previous knowledge on the researcher's interpretation of data. There is a belief that data should express themselves freely without any bias from the researcher's preconceptions.

There are qualitative researchers on the other hand who disagree with this view. They suggest that bias is unavoidable when it comes to search a phenomenon and that it is impossible for knowledge to emerge without some previous conceptual structures. Consequently, a researcher should start by searching the literature (Elliott and Timulak, 2005).

Although there is a debate about the influence of the researcher being engaged with the relevant literature and the timing of data collection (Braun and Clarke, 2006), it is rarely sufficient to focus purely on the collected data when carrying out a qualitative analysis. The researcher already has knowledge about the specific area of the research and he/she can be influenced by that during data analysis (Green and Thorogood, 2009). It is also beneficial to conduct a literature review before data collection as it may help the researcher to formulate and refine the research questions. This prior knowledge would help the researcher to get a deeper understanding of the phenomenon and make him/her aware of the theories and knowledge, and hence may shape the data collection, analysis and interpretation (Elliott and Timulak, 2005).

5.1.5 Sampling in qualitative research

The purpose of a qualitative study is to get a deep understanding of the phenomena under study and not to generalise the results of the study. For that reason the sample should be carefully selected to reflect a better understanding of the research focus.

A big sample size is not so important in qualitative research. What is more important is to reach an acceptable level of validity and information richness of the selected cases and the observations/analytical capabilities of the research (Durning et al., 2011).

Purposive sampling is widely used in qualitative research. This sample is characterised by the use of judgement and a deliberate effort to include typical groups in the sample (Kerlinger, 1986). During the process of purposive sampling, the researcher is striving to get a representative sample. An accessible sample can be used, bearing in mind the inclusion of different genders and origin. Maximum variation sampling strategy is one of the suggested strategies for purposive sampling. This could be theoretical or time- or place-based (Carter and Little, 2007, Durning et al., 2011).

Sample size cannot be predetermined in qualitative research. However, sampling can be continued until data saturation is achieved, *i.e.* no more pieces of new information are emerging from collecting more data. Other considerations are also important such as, time and money allocated for the research (Carter and Little, 2007).

5.1.6 Data collection in qualitative research

Think-aloud methods and the verbal probe method can be used for data collection in qualitative research (DiIorio, 2006). Verbal protocol analysis is following the principles of information processing theory, (described in Chapter 2 on page 29).

Verbal probing technique is one of the favourable verbal recording techniques used in qualitative research (Lubarsky et al., 2013). It is directed to produce a focussed and productive form of verbal record in which the interviewer tends to follow up the question posed at the beginning of the face-to face interview. However, it has the disadvantage of potential interactivity with the interviewer and the possibility of bias. It also requires careful training of the interviewer (Boulouffe et al., 2013).

Thinking-aloud interviewing is the other approach for data collection used in verbal protocol analysis. Protocol analysis of the verbal data has been used in the field of health care and follows suggestions of Ericsson and Simon (1993), who suggested that verbalisation is a type of analysable and recordable behaviour.

There are three main assumptions regarding the thinking-aloud method which are mentioned in the literature. These are: information processing theory explains human cognition; cognitive processes can be verbalised; and think-aloud indicates the information that the individual focuses on in the time (Newell and Simon, 1972, Simmons, 2003).

As described by van Someren *et al* (1994) thinking aloud is a method that enables the researcher to get a deep understanding of a phenomenon while the individual is engaged in a specific task. It is considered a direct method to get an insight into the knowledge and methods of human problem-solving. This method is widely used by psychologists and other social scientists. It is also considered as a relatively efficient way of data generation in almost all heath topics especially when used in an appropriate way in which the researcher reflects on how the collected data inform the research context and analyses the research questions through his/her good interviewing skills (Green and Thorogood, 2009).

The interviewer should be trained to induce the participant to think aloud. However, as instructed by Ericsson and Simon excessive training in think–aloud protocols should be avoided and the subject should not focus on the technique of think-aloud, rather he/she has to use think-aloud as a tool to understand his/her mental processes (Hornos et al., 2013).

The original proponents of this method, Ericsson and Simon, argued that think-aloud is an effective method for cognitive research in that: (1) when the subjects are thinking-aloud they use their short-term memory for self-reporting. (2) During this self-report subjects can produce a non-reactive type of self-report, which is not contaminated by the process of think-aloud method (Hornos et al., 2013).

Willis has listed three main advantages to think-aloud methods, as follows:

- Little influence by the interviewer on subject's response to the questions. Therefore, no bias is caused by the interviewer as he/she is letting the subject self-report his/her own thoughts with little interference.
- Little training is required for the interviewer
- An open-ended format is a feature of this method, as the subject is occasionally guided by the interviewer (Boulouffe et al., 2013).

Willis has also reported some potential disadvantages of the think-aloud technique, as follows:

- Subjects may require some training because this task might be unusual for most people
- Some subjects are not good at thinking-aloud, especially when they have low skills in the language in which the interview is conducted, (as is the case of the participants from Taibah School described below).
- It may create a burden on the subject, as he/she is the main speaker. There is a debate about the non-contamination of the subjects' responses, as thinking aloud may make the subjects focus on the technique rather than the research questions
- The probability for the subject to stray from the task. Being under minimal control, the subject may spend more time answering a specific question or even deviate from the original discussion
- It is possible that the subjects give an un-codeable response
- Subjects may simply state answers to the questions without elaborating on their thinking

  Adapted from: (Boulouffe et al., 2013)

Despite what is stated earlier about that verbalisation can reflect cognition, Green and Thorogood (2009) added to the limitations of think-aloud as it only provides access to what individual says and not what he thinks or does. Furthermore, the analysis of data depends on local, cultural, and linguistic knowledge of the researcher. For that reason the recorded interviews were transcribed by a native speaker, as will be described later. As reported by Willis the think-aloud method is relatively simple to conduct but the most critical issues arise during the analysis of the think-aloud protocol as being varied, complex and highly dependent on the subjective interpretation of the researcher (Boulouffe et al., 2013).

Other procedures used for data collection in qualitative research include ***Vignettes.*** Vignettes are 'short *stories or descriptions of a hypothetical respondent that are used to investigate a subject's cognitive processing with respect to survey-relevant decisions'* (Boulouffe et al., 2013). Vignettes are triggers to obtain responses about a specific situation or questions. They may include texts, images or any other forms of triggers (Young, 2005). Vignettes have been extensively used in medicine to assess decision – making and problem solving abilities in medical students. Furthermore, they have also been widely used in medical educational research (Peabody et al., 2004).

The use of ***Card sorts*** is another procedure for data collection in qualitative research. It is a systematic means to examine how a subject thinks about a key topic. Focussing mainly on how individual organises concepts, in particular the belief of the subject about what a concept includes or excludes. During the process of card sorting the subject is asked to sort different cards into piles that go together (Boulouffe et al., 2013).

Field-based probes is also used a method for data collection in qualitative research. In this type of cognitive interviewing, the subjects are interviewed through probing technique while being in the field. It can be conducted either concurrently or retrospectively of the task performed. Other procedure such as analysis of recoded speech or behaviour using audio or video tapes, and analysis of texts or documents may be also used to collect data for qualitative research.

5.1.7 Data analysis in qualitative research

This important phase in qualitative research is considered to be complex and there is a lack of a clear description for qualitative data analysis in the literature (Thorne, 2000). Understanding this process is important not only to interpret the research findings, but also for the readers to make sense and understand the research conducted. There is a stress on the importance of qualitative data analysis, which should be careful, thoughtful, and rigorous (Pope and Mays, 2006). As stressed by Green and Thorogood (2009), qualitative analysis of data depends on imagination and the ability to make links, together with the knowledge base to draw upon. However, qualitative data analysis should not merely be thought of as entirely invented by the researcher. It should be rigorous and reflective of the links between the collected data.

Even with the use of computer programmes for data analysis, the inductive reasoning of data analysis is conducted by the researcher and the role of these programmes is limited to organisation and sorting of themes originally created by the researcher (Green and Thorogood, 2004). In most cases of qualitative data analysis, the researcher may frequently intervene to illustrate the meaning behind the data and implies his/her interpretation (Green and Thorogood, 2009).

There are different strategies for qualitative data analysis. ***Constant comparative analysis*** is one of these strategies. It is the basis of analysis in thematic analysis, naturalistic and interpretive description. In this case the researcher constantly compares and contrasts one piece of data to all others. It was originally developed and used for grounded theory (Thorne, 2000).

Thematic analysis of think-aloud interviews is a process by which the researcher seeks patterns emerging from data and then applies these codes to the entire data. Emerging patterns depend on the focus of the study (Darlington and Scott, 2002).

Thematic analysis *'is a way of seeing'* (Boyatzis, 1998). Often, what one sees through thematic analysis does not appear to others, even if they are observing the same information, events or situations. Thematic analysis is described as "by *using data such as interview notes or transcripts; the researcher looks through them to categorize respondents' accounts in ways that can be summarized"* (Green and Thorogood, 2009). This is essentially a comparative process, by which the various accounts gathered are compared with each other to classify those 'themes' that recur or are common in the data set. Thematic analysis may go deeper to link different themes and find new connections between data sets. Deeper thematic analysis may lead to a constant comparative method (*grounded theory*) or *framework analysis*.

Following the guide suggested by Green and Thorogood (*ibid*), the first step in framework analysis is to get *familiarised* with the data. The second step in the process is to carry out a thematic analysis to *develop a coding scheme*. The themes in the data are set to constitute labels for codes. *Indexing* is the third step in thematic analysis. It refers to the process of systematic application of codes to the whole data set. *Charting* is the fourth step. It involves rearranging of the data according to the thematic content to facilitate comparison between cases and within each case. The charts contain summarised thematically arranged data.

In order to move from thematic analysis to framework analysis, a further step is needed which is *mapping and interpretation,* (see

Figure 5:1). This can be defined as looking at relationships between the codes. Framework analysis also has the product of developing practical strategies based on the analysis carried out. So, it is policy oriented.

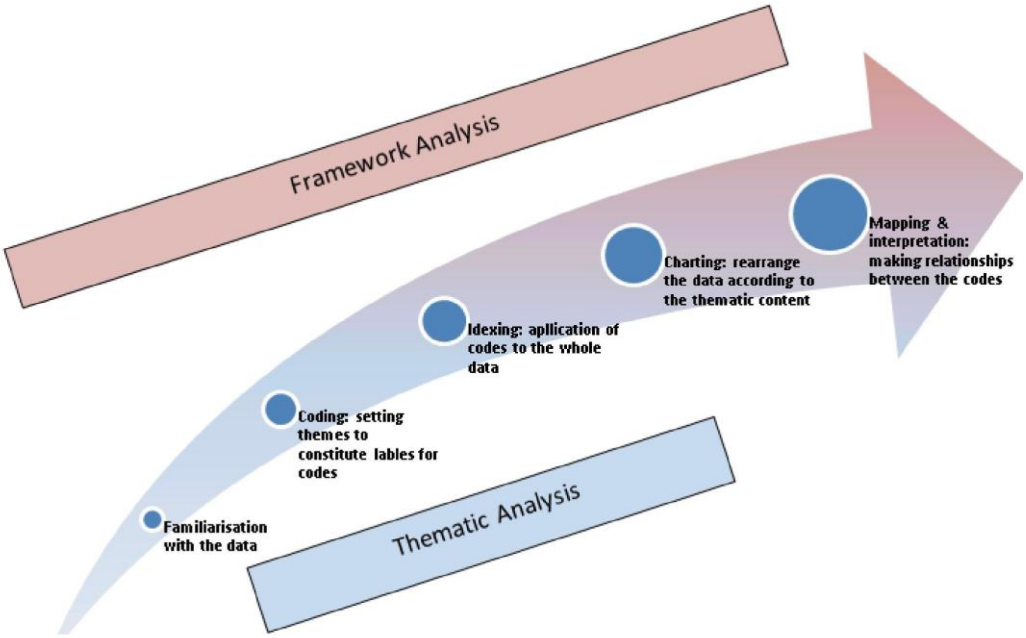

Figure 5:1: The process of thematic and framework analysis

Although thematic analysis is widely used and should be considered as a foundational method for qualitative analysis, it has been argued that it is still rarely acknowledged and poorly explained (Braun and Clarke, 2006).

Two ways of thematic analysis were identified as *inductive* (bottom up) and *theoretical* or *deductive* (top down). In the first type analysis is data driven in which the researcher tries to extract themes from data without trying to fit data into a pre-existing framework or researcher's analytic theoretical conceptions. On the other hand, if the researcher tends to use the theoretical thematic analysis he/she depends on his/her theoretical or analytic interests, and data analysis will occur in an analyst-driven way.

Two levels of analysis have also been identified. A *semantic* (explicit level) refers to the process in which the researcher organises and summarises the data attempting to identify the significance of the evolved patterns, their meanings and implications often relating these patterns to literature. In contrast, the latent level of thematic analysis extends to involve processes of interpretations, assumptions and conceptualisations of the data and examines the underlying ideas.

The most common type of qualitative data analysis in the health care sector is analysing the content and categorising specific emerging themes (Green and Thorogood, 2009). In conclusion, the depth and the level of analysis are variable and mainly depend on the research focus, aims and objectives. At the end the researcher should be able to provide proves to support the study findings and answer the research questions.

Framework analysis is another strategy for data analysis in qualitative research. To go farther with the thematic analysis, framework analysis was developed by the National Centre for Social Research (NatCen) in 1980s aiming to generate policy and practice-oriented findings. It is defined as 'a content analysis method which involves summarising and classifying data within a thematic framework'.

Protocol analysis is another type of qualitative data analysis. With the assumption made that it is possible to instruct the participant to verbalise his/her thoughts in a manner that does not alter the sequence of thoughts mediating the completion of the current task, protocol analysis is considered as a valid methodology on thinking (Psychology Faculty at Florida State University, 2013).

Protocol analysis has three steps. These are: *referring phrase analysis*, to isolate the specific information that the participants focus on during their reasoning process; *assertional analysis*, refers to the identification of the relationship participant formed between and among the concepts identified in the referring phase analysis, and *script analysis*, which provides an overview of the cognitive process and thinking strategies that the participants used in their reasoning task.

5.1.8 Validity and reliability in qualitative research

Validity and reliability are both important to be considered during data analysis (Green and Thorogood, 2009). In qualitative research they may be referred to by using different terms, which include credibility, transferability, dependability, confirmability, substitutes for internal validity, external validity, reliability and objectivity.

There are multiple suggested techniques to aid validity and reliability of qualitative research these include *respondent validation* or *member checks*. In case of respondent validation participants can check the research findings against what they actually meant during data collection. They can also check the transcribed materials of their interviews. Codes can also be created and checked by another member and studied for consistency between the different coders in a process known as member checks (Merriam, 2009).

To support the credibility of qualitative research the researcher may include quotations of the participants' speech as examples of emergent codes and themes. Numerical counts of the cases that share common themes together with reporting the deviant cases could also have an effect in raising the credibility (Green and Thorogood, 2009).

In this part of the current chapter we have discussed the use of qualitative research, its importance and its history. We have also presented general information regarding the characteristics of this type of research including approaches, sampling, data collection and data analysis. The following section will discuss the qualitative study conducted in order to answer the research question posed in Chapter 1.

5.2 Clinical reasoning in final year dental students; a qualitative cross curricula comparative study

5.2.1 Introduction

As discussed earlier, there is a general agreement about the paramount importance of clinical reasoning skills in health professions. However, clinical reasoning research is lacking in the field of dentistry (Maupome, 2000, Maupome et al., 2010), especially in what the term implies from the students' view point. To our knowledge there is no research conducted to examine clinical reasoning from the students' point of view or to shed light on dental students' understanding of clinical reasoning and its associated prerequisite. The role of undergraduate curriculum models in the development of this skill is also not clear (Zadik and Levin, 2007, Norman, 2003).

As mentioned in Chapter 2 research in clinical reasoning was mostly directed towards observation of novices and experts in action involving analysis of their problem solving steps and their decision accuracy. It also speculated the assessment of dysfunctional behaviours and the cognitive process involved in clinical reasoning (Hendricson et al., 2006). The descriptive-interpretive approach is lacking in studies of clinical reasoning and there is a call for including this particular approach in clinical reasoning research in dentistry (Khatami et al., 2008a).

In a given situation where two students are asked to go through a dental case, they might reach the same diagnosis. However, their reasoning process might be different. One of them might go through ritual protocol of history taking, examination...*etc.* and to collect all the information he/she requires in order to reach to an acceptable diagnosis. On the other hand, the other student might prefer to start by estimating possible differential diagnoses and work through them to support or reject these possibilities. Although the two students gave the same diagnosis, their problem solving strategies were different. For that reason, protocol analysis of the think-aloud method may be used to get a deep understanding of the problem-solving processes used by each student. It also provides a clear description of how each of them reached the final diagnosis. Moreover, it can explore when a student encounters difficulties and when he/she get confused.

The methodology chosen for the current research is a thematic analysis using a think-aloud method of semi-structured individual interviews, including vignettes, with eighteen final year dental students from three dental schools implementing different curriculum models. In order to get a deep understanding of the process of clinical reasoning and the impact of the different models of the undergraduate dental curriculum, this qualitative study is conducted to complement the quantitative research described in Chapter 4.

For the study of a complex process like decision making during clinical reasoning, researchers cannot neglect the effect of many factors in making decision. In the field of dentistry, in particular, there is an endless list of factors affecting this process, such as time, environment, price of treatment, patient's behaviour and attitude, (see Chapter 2).

The think-aloud method suits the purpose of the current research because it is claimed to be the effective way to access the cognitive processes used in clinical reasoning (Simmons, 2003). As described by Newell and Simon in 1972, think-aloud is a qualitative technique of collecting verbal data about cognitive process during a problem task.

The objectives of the current qualitative study are to:

- Explore the meaning of clinical reasoning and the learning opportunities that facilitate it as explained by students
- Describe the different reasoning processes used by dental students when they discuss clinical vignettes
- Examine the similarities and differences between three samples of final year dental students in their understanding and practicing clinical reasoning in order to find any association between the different curriculum models and the development of this skill

5.2.2 Materials and methods

Ethical approval was obtained from the University of Nottingham to conduct this study, (see Appendix 1). Three dental schools were identified as places for the current study. These schools were selected based on their varied undergraduate curriculum models. These were: the Dental School at the University of Birmingham, which uses an integrated type of curriculum, and the Dental School at the University of Manchester, implementing a PBL curriculum, in the UK and the Dental School at Taibah University in Saudi Arabia (SA), with an integrated curriculum. Chapter 3 presented details concerning these three dental schools annotated according to how they fit into the SPICES model and the Integration Ladder framework (Harden, 2000, Harden et al., 1984), and other aspects important for the current research.

5.2.2.1 Vignettes

The methods used for this study is a thematic analysis of transcribed semi-structured interviews. Qualitative interviewing is the preferred method to get high level of understanding of a phenomenon in question (DiCicco-Bloom and Crabtree, 2006). Because we aimed to get deep understandings of clinical reasoning as a phenomenon in dental students this method suits the purpose of the current study.

Four questions were thought to deeply address the understanding of clinical reasoning skill by the participants, their personal experience of this phenomenon and their learning experience of clinical reasoning. These questions asked the following:

- *What do you understand by clinical reasoning?*
- *Give me an example of clinical reasoning you have engaged in*
- *How do you learn clinical reasoning?*
- *Give me an example of learning clinical reasoning*

The remaining semi-structured questions were related to presenting a dental clinical case during which the participants were asked to describe the problems found in the case using intraoral pictures and dental radiographic images. They were also asked to go through the process of management options. Some questions may be altered or modified during the interview according to the emerging conversation.

Clinical vignettes were created and incorporated into a patient case. The single patient case was used in order to keep the conversation confined and simple for the participants to relate and associate the entire patient's information provided in the different vignettes. Clinical vignettes were discussed in the same order presented in Table 5:1.

Interview protocol was developed by the researcher and agreed by the supervisor, who is a Professor of Medical Education. In order to ensure the validity of the proposed clinical vignettes, feedback was obtained from five experts in dental education, oral pathologist and dentists. These experts were selected from Canada, SA and the UK. Dr. Khatami, who developed a framework of clinical reasoning in dentistry, was one of them. They reported that the questions and the case scenario involved in the interview protocol were appropriate to get a deep understanding of clinical reasoning. They also confirmed that the clinical case was suitable for the final year dental students.

Table 5:1: Situational vignettes for the semi-structured interviews included the presentation of a single patient case

Vignette1	A 41-year Asian woman comes to your dental office. Her chief complaint was 'I want to restore my decayed teeth and replace my missing teeth'. She is medically fit and is not taking any medication. She reported that she had multiple extractions in the past due to caries and she is now brushing her teeth twice a day and sometimes she uses dental floss.
Vignette2	I need you to think aloud and describe the oral problems for this patient
Vignette3	How would you manage this patient?
Vignette4	What do you think of the radio-opacity in the maxilla? What information will help you in managing this?
Vignette5	You notice this lesion in her buccal mucosa. The lesion is asymptomatic and bilateral How do you diagnose and manage this lesion?

In depth individual interviews were conducted with the students and a thematic analysis was run using NVivo Version 10 (QSR International Pty Ltd, Doncaster, Vic, Australia) software to sort and organise the emerging themes analysed by the researcher. A decision was made to use *thematic content analysis* of qualitative data for the following reasons:

- There was a need to get a deeper understanding of the development of clinical reasoning skills in dental students by getting a general view of the emerging themes that were common in the current study sample.
- The need to find similarities and differences, if any, between the samples among the different dental schools to study the possible relationship of the type of curriculum and the level of clinical reasoning.

Codes were decided to be inductively and deductively created. Khatami's research in clinical reasoning provided information about the common emergent themes in dental students, which might be expected in our sample (Khatami et al., 2011). Data driven thematic analysis is suggested by Boyatzis (1998) as being the most recommended and the most fundamental method to develop themes and codes.

Because the current research implements a pragmatic approach, mixing of quantitative and qualitative methods were allowed if it helps to answer the research questions. In the current study quantitative data analysis was used, although it was kept to a minimum, to compare the time spent by the interviewees during the interviews. The used tool was IBM SPSS version 21.

5.2.2.2 Procedure and data analysis

The level of the thematic analysis was chosen to be at a latent or interpretive level in addition to manifest, semantic or explicit level (Boyatzis, 1998). This was suggested in order to get an in depth understanding of the clinical reasoning process.

Literature review was conducted before data collection and carried out through the phase of data analysis. As suggested by Tuckett (2005), the engagement with the literature before data collection makes the qualitative researcher more sensitised to subtle features of the data and enhances the analysis.

In the current study, the researcher was carrying out the quantitative study, (described in Chapter 4), concurrently with the qualitative data analysis. The results of the online Clinical Reasoning Test (CRT) provided some ideas about the characteristics of clinical reasoning skills in the sample, especially the answers to the open ended questions. Identification of some similarities in the responses among a particular cohort of students from a particular dental school was possible. The researcher also got a an overview about what to expect during interviewing students from a specific school *e.g*. Manchester students were commonly mentioning evidence based dentistry and having another opinion when not sure of the possible diagnosis.

Data analysis was carried out concurrently with data collection. As described by DiCicco-Bloom and Crabtree (2006) this process, in which the researcher conducts data analysis and data collection simultaneously, is ideal for the qualitative research aiming to get more understanding of the interview questions by the researcher and informs both future questions and sampling. It also eventually informs the researcher about when data saturation is reached.

The analytic strategy used for the current study was following the '*editing approach'* which is describe as the process in which the investigator reviews text segments in the same way as editor does while making interpretations to identify patterns (*ibid*). Data were analysed carefully in a recursive process going back and forth during the analysis to formulate the different themes. This process was suggested as being common for qualitative research (Ely et al., 1997).

The pattern of data analysis was following a process called 'immersion and crystallization' by Miller and Crabtree (Miller and Crabtree, 1992). Immersion is '*a process whereby researchers immerse themselves in the data they've collected by reading or* *examining some portion of the data in detail*'. Crystallization is '*the process of temporarily suspending the process of examining or reading the data (immersion) in order to reflect on the analysis experience and attempt to identify and articulate patterns or themes noticed during the immersion process*' (Cohen and Crabtree, 2006). These dual processes continued until all the data have been analysed and patterns have emerged from the data.

Themes were agreed upon with the researcher's supervisor. As suggested by Green and Thorogood (2009), it is always advisable to agree upon coding themes and their meanings with supervisor if the researcher is not working in a team. The transcribed texts were analysed by the researcher and checked by a medical student at the University of Nottingham in order to ensure the reliability of the research.

In reporting the results each participating student was identified by a letter and a number. The letter represented the initial of the dental school and the number referred to student's order in which he/she was interviewed. (B1) is the first interviewee from the dental school at the University of Birmingham and so on.

5.2.2.3 Participants

A purposive sample was used for this study. The total number of participants was 18 final year students. Interviews were conducted during July to October, 2013. At the University of Birmingham 6 interviews were conducted with 2 male and 4 female students. At the University of Manchester a total of seven students were interviewed two of them were male.

Finally, at Taibah University five male students were interviewed. This was the first cohort of students to graduate from this newly established school. There had been a decision to establish the dental school starting by running the dental undergraduate course for male students. The program was then available for female students a few years later. All final year students were male during the time of the current study.

Criteria for the selection of sample were: final year undergraduate students, from different dental schools using different types of curriculum. Students were chosen to be in their final year in order to ensure maximum level of knowledge was obtained and to exclude other factors which can affect the results such as the chronology of the syllabus (timing of clinical training and taught dental subjects). Putting these criteria would allow fairer comparing and contrasting between or among the samples.

Students were asked to provide their email addresses at the end of the online CRT, (Appendix 2), if they were willing to participate in the current qualitative study. Communication was then carried out through emails to arrange for interviewing. Consent forms were sent to the students' e-mail addresses. Description of the study purposes and strategies were given and participation was totally optional. Compensation for time was given in the form of £10. Anonymity of the interviewees was established and maintained, *i.e.* no personal identifications were obtained from the participants during the interviews. Instructions for think-aloud was verbally mentioned to the participants before starting the interviews, (see Appendix 6). Visits to the dental schools were carried out by the researcher in order to explain the aim of the research to the students and encourage them to participate.

5.2.2.4 Venues

Interviews were conducted in quiet places including a lecture theatre and students' lounge at the Dental School at the University of Manchester. At Birmingham Dental School the course director kindly provided her office for the interviews. However, providing a place to conduct the interviews was not easy in the case of Taibah sample. Religious and cultural barriers made a public space the only acceptable place for a female researcher to interview male students. For that reason, interviews were conducted in a relatively quiet corridor at King Fahd Hospital in SA.

5.2.2.5 The researcher

The researcher who carried out this study was a general dentist with a masters' qualification in medical education. The researcher was bilingual, Arabic was her native language and English was the second language. The researcher was responsible for interviewing the participants and recording these interviews using a digital recorder.

Data were collected by the researcher in an interactive way. Probing questions were sometimes used to facilitate the conversation especially when the participant straggled to answer the first question stating '*What is clinical reasoning, or what do you understand by clinical reasoning?*' Examples of probes used were: '*at clinic… what do you do with the patient? When you have a case at your dental office, how can you deal with it?'*

Although intervention was kept to a minimum, the researcher sometimes used prompts trying to be a facilitative audience for the respondent's talk. Head-nodding as a non-verbal cue was also used to express the researchers' interest. Some verbal prompts such as '*uh-huh, mm, great, yes, good…'* were also used.

Before carrying out interviews, the researcher practiced interviewing some of her dentist friends and received their feedback. Dentists were chosen for practicing the interviews because they can easily understand dental terms and discuss the dental vignettes used for the current study. They were also able to explain in the researcher's native language what she needed to improve or alter, so that she could get a deep feeling for it.

To improve the reliability of the interviews, notes were taken during the recorded interviews. Notes were taken only when there was a feeling of the need to include some non-verbal responses such as discomfort or hesitation. The researcher tried to keep them simple and infrequent so as not to disturb the interviewees or let them feel that she was not engaged with them.

Transcription was provided by a private professional to overcome the disadvantage of being a non-native speaker of English. However, transcriptions were checked back against the original audio recordings multiple times. The transcriber missed some of the dental terms such as OPG, peri-apical and a few others. So these have been added to the transcripts and replaced the dots left by the transcriber.

Reading the transcripts many times before the coding begins helped to familiarise the researcher with all aspects of the data and suggest possible patterns.

5.2.3 Results: thematic analysis

In this section, emergent themes will be described, followed by detailed data analysis and comparisons of the samples and finally discussions of each individual major topic area.

Common themes emerged from the data and interpreted by the researcher. These themes were illustrated in mind map forms to reflect the relationships between the emergent codes, see Figure 5:2-Figure 5:5. Mental maps are visual displays that can be used to present codes in qualitative research. Similarities and differences in codes could be presented in the form of mental maps. Items may or may not be presented hierarchically (Rayan and Bernard, 2000).

This section is organised in the following format:

1. Discussions of the emerged themes in the data separately in each of the two major topic areas *i.e.* **students' understanding of clinical reasoning** and **the process of clinical reasoning**
2. Detailed data analysis after the thematic analysis of each topic area, making comparisons between the three groups of students studying at different schools with specific curriculum models
3. A separate discussion section after every major topic area

This organisation allows the reader to go through the interpretation made by the author close enough to the themes discussion, avoiding the intermingling between the researcher's voice and the participants' voice (Darlington and Scott, 2002). A global discussion section will be also presented at the end summarising the key findings in this qualitative research.

5.2.3.1 Emergent themes

This section will explain the results of thematic analysis with a focus on the emergent themes without making comparisons between the three students' samples. Examples of data coding is presented in Appendix 7.

5.2.3.1.1 Students' understanding of clinical reasoning

When the participants were asked about their understanding of clinical reasoning **uncertainty and unfamiliarity with the term clinical reasoning** was a common theme emerging from the data *e.g.*

> "*Clinical reasoning? I don't really know much about clinical reasoning*" (B3).

However, a few students provided acceptable definitions for clinical reasoning *after probing e.g.*

"I think with the different treatment options, deciding what the best option is for the patient, and reasoning up which is the best for the patient, and which has the best outcome" (B3).

Reflecting on the meaning of clinical reasoning appeared when the participants answered the second question in the interview. This question was '*can you give an example of clinical reasoning you have engaged in?*' Participants' responses varied, and can be classified into three categories. The first category of responses was **providing specific examples of clinical cases referring to specific patients they have encountered either in clinic or mentioned by their tutors** *e.g.*

"I have a patient at the moment who has a recurrent TMD[6] problem so she has quite a few failed fractured amalgam …" (M6).

The second category of examples was **providing examples of general dental cases with no mention of a specific patient** *e.g.*

"So say you have got something like someone with Peri-apical Pathology, so you would look at it…. You would probably assess the bone levels, assess the prognosis of the tooth, ask the patient for their symptoms, ask for them for… So you would see their odds as to their symptoms. You'd be able to assess the tooth itself, see if it's highly carious clinically, see what it looks like, and then you would obviously choose either root canal treatment as the best viable option, or an extraction." (B4).

The last category was **providing general examples without mentioning a specific clinical problem** *e.g.*

"When a patient come to the clinic and ask him about the chief complaint, diagnose him, take information from him, something like that" (T2).

[6] TMD stands for temporomandibular disorder

"*I think with the different treatment options, deciding what the best option is for the patient, and reasoning up which is the best for the patient"* (B3).

Please refer to Figure 5:2 for the emergent themes regarding what clinical reasoning means to the students' samples in thematic analysis.

When the students were asked to provide methods of learning clinical reasoning from their points of view, common themes emerged such as **PBL, on clinic, experience of colleagues and tutors…*etc*.** These themes are presented in Figure 5:3. **Experience and own work** were seen as the most important methods for learning clinical reasoning by the participants. Some of the interviewees saw the development of clinical reasoning skill as **an incremental process** stressing on the importance of **experience** in fostering the development of this skill *e.g.*

"*… I think, then the real clinical reasoning comes with experience so, once you start seeing patients and seeing what... you know, you can have textbooks and you have guidelines but you've got a patient at the end of the line and receiving this treatment so we need to think about that as well*" (M7).

"*It's more just by experience, we're not actually taught it physically*" (B2).

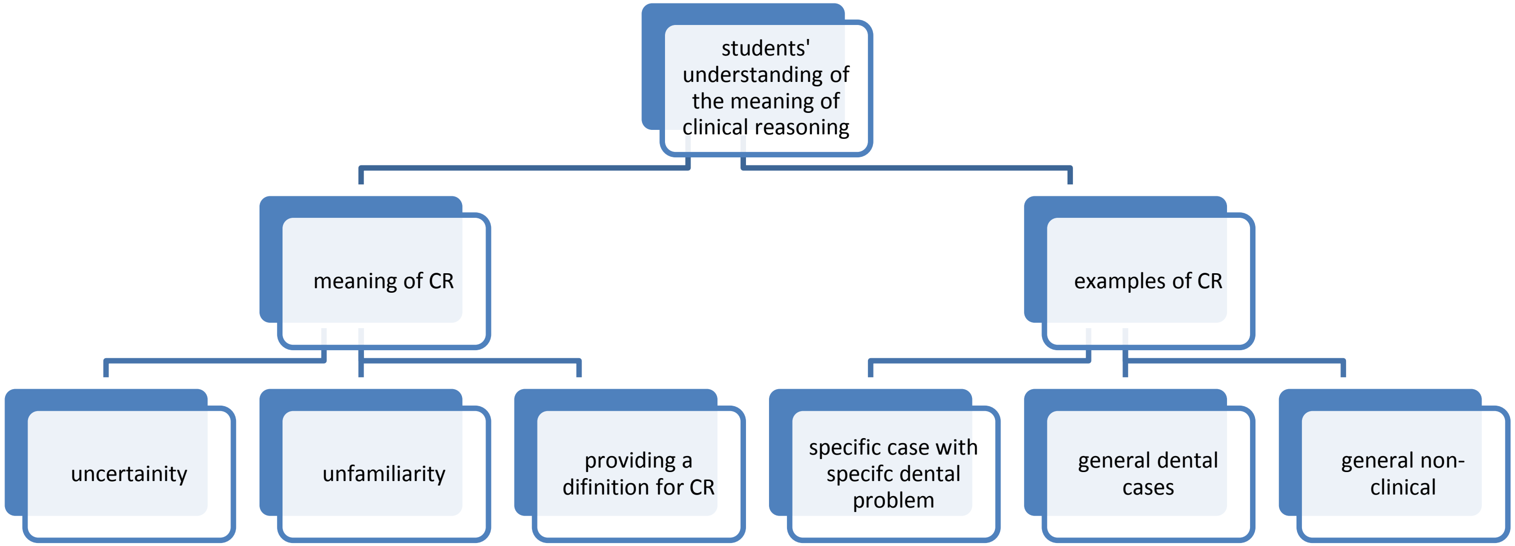

Figure 5:2: Common themes presenting the students' understanding of the meaning of clinical reasoning

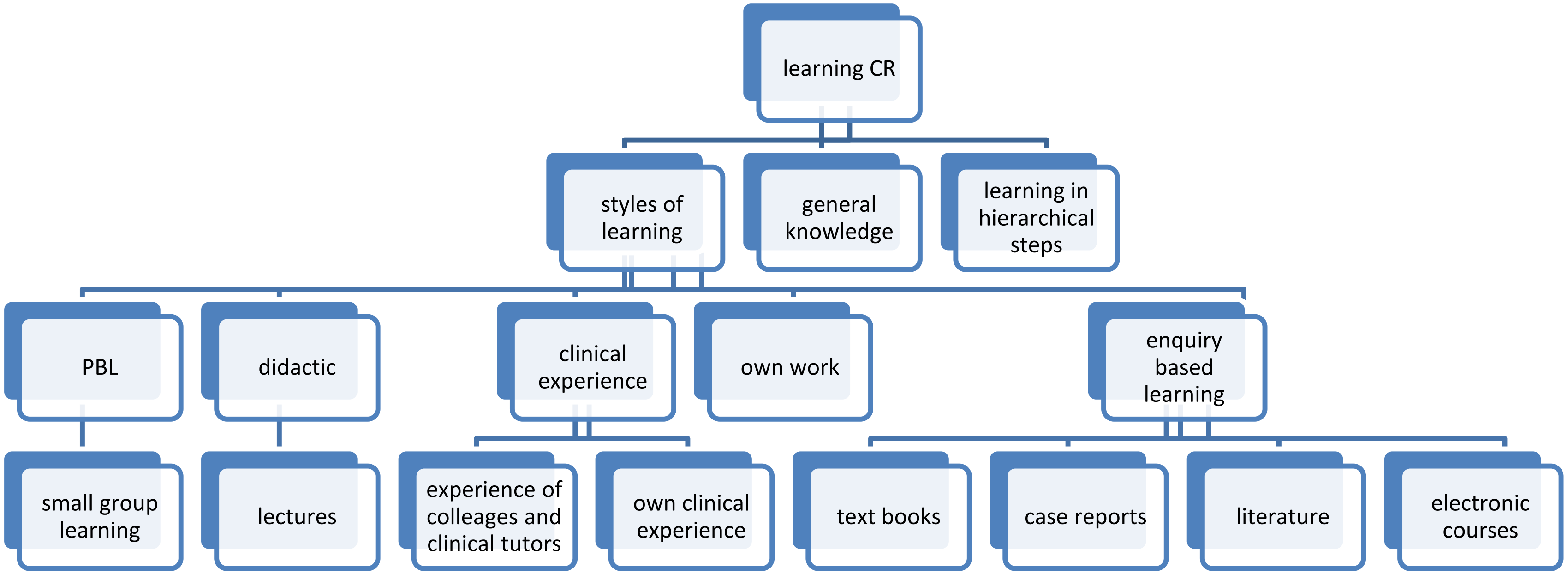

Figure 5:3 Methods of learning clinical reasoning as described by the interviewed students

5.2.3.1.2 Reasoning processes

This section will discuss the themes regarding the second topic: 'reasoning strategies and processes used by the interviewees when they discussed the clinical vignettes'. Different reasoning processes were used by the participants at the three different dental schools. *Scripts and pattern recognition* was one of them. This rapid process of reasoning enables individuals to retrieve disease scripts and is triggered by visual cues and pieces of information presented in case description. Colour and appearance of gingiva are the required visual cues to trigger **periodontal scripts** supplemented by special tests like bleeding index and pocket depth. Most of the interviewed students were able to describe the condition of the periodontal tissues by just looking to the presented frontal view. An example of this specific script was provided as:

> *"Her gingiva seem to be in quite a good condition, doesn't really look like there's any redness or rolling of margins or anything like that…"* (B1).

Dental students mainly detect orthodontic problems *e.g.* mal-alignment and cross bite by their appearance. They may request further investigations afterward. Most of the interviewed students from the three dental schools were able to assess the orthodontic condition of the patient by pattern recognition using **orthodontics scripts** *e.g.*

> *"Cross bites in some areas"* (T2).

Caries script is used to diagnose the most common disease of teeth. Almost all the interviewed students were able to detect carious lesions from looking at the views of upper and lower arches *e.g.*

> *"She has multiple missing teeth and multiple caries"* (T4).

Diagnosis for the radio-opacity of a retained root using **pattern recognition** was effectively used by some participants. They were mainly looking for radio-opacity degree matching the tooth structure and the presence of lamina dura around the root[7] giving it a defined outline. Six students used pattern recognition to correctly diagnose the retained root *e.g.*

> *"It looks like a retained root"* (B4).

> "*Maybe it will be a remaining root. That's all*" (T3).

Some participants have made the correct diagnosis of the white lesion in the buccal mucosa using the pattern recognition process of clinical reasoning *e.g.*

> "… *So, it looks like it's white, like striated pattern, so, I know it's ridiculous but it looks like Lichen Planus*" (B5).

Forward and backward reasoning and a combination of both were different processes of clinical reasoning used by the participants. **Forward (inductive) reasoning** is a process by which the student uses the patient's information and works through the given data and criteria to reach a specific hypothesis and diagnosis. Only two interviewees used this process to make their right diagnoses, as follows:

> *" There's a radiopacity about one to two centimetres in diameter which is obviously some form of dental tissue. Things it could be would be a retained root potentially*" (M1).

> "*By scratch the lesion. if it comes or not, Just that. Lichen planus*" (T3).

Another participant used this approach, but could not provide a correct diagnosis *e.g.*

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[7] Lamina dura is a radiographic term used to identify the radiopaque demarcating lining of an alveolus surrounding the tooth root.

"*Maybe – if it wipes off then it might be candida. If it didn't… are there any – are there white patches anywhere else maybe, but I'm not sure*" (M6).

Backward (deductive) reasoning is when the student suggests hypotheses and works through to either accept or reject them. It is often a characteristic of novice students' reasoning. Some interviewees used backward reasoning while diagnosing the remaining root *e.g.*

" because what I'm looking for is like a lamina dura around the roots, but you would see… But with all the radiolucency you can see all around, that's a bit unusual for a root to have that, but it was an edentulous space in the photograph, so what else could it be?"(B2).

A few interviewees used the backward strategy to make their diagnoses of the white lesion *e.g.*

" It could be lichen planus, because it looks… it is quite white and it is striated, and it is bilateral, it is usually a sign of lichen planus. It could be some other form of leukoplaqia, but if it is asymptomatic, because lichen planus usually is asymptomatic, I would probably say it is lichen planus" (B3).

Only three participants used a **combination approach** to reach their diagnoses *e.g.*

"*So I'd palpate there and I'd feel if I can feel any unusual protuberance or anything like that. I mean it could be a retained root from a previous extracted tooth although I can't really see much canal root anatomy. So I'm not sure whether it is a retained root or not, but it's likely to be one*" (M2).

Decision analysis was another common theme. When participants were engaged in the reasoning process, they were actually using their knowledge, own experience and colleagues' experience to provide diagnostic or management options and finally, evaluate these options *e.g.*

> *"a denture or even bridge work if her perio is up to scratch, but it's quite long spanning edentulous areas so maybe because she's got multiple it might be better to put a denture in"*(B1).

Involving the patient in making decision was common among the UK participants *e.g.*

> *"but she has gaps here and there and she's worried about it, so we need to discuss the options with her"* (B2).

Another theme was **referring to the information provided by the interviewer** *e.g.*

> *"There seems to be obviously a lot of spaces in-between her teeth which as you mentioned, due to decay in the past,"* (M2).

Asking for more information was also detected during the thematic analysis. Some of the participants asked the interviewer to provide more information either to check their understanding or to support their decision *e.g.*

> *"Could I just ask where are the missing teeth?"* (M3)

Other themes also emerged from the data. However, they were not common among the participants. These include **referring to professional integrity** which was mentioned twice by one participant *e.g.*

> *"Okay. So when I'm looking at this patient I'm going to look through each of the different sort of types of disease that we deal with as dentists"* (M1).

Another uncommon emergent theme was **mentioning ethical concerns.** One participant discussed some issues which he felt might deviate from ethical concepts such as having too many radiographs taken for the patient, as follows:

> *"You have to consider when you are taking a radiograph are you going to get a better outcome or be able to make a better clinical*

decision by taking another radiograph. The OPG[8] that's quite a lot of exposure already, you can see the periapical area" (M6).

Another participant has stressed on the importance of taking the patient's consent, as follows:

"we need to consent for anything we do" (M1).

More details regarding the thematic analysis and the comparison between the three groups of students will be provided below.

5.2.3.2 Comparison between the different students' samples regarding their understanding of clinical reasoning

After describing the emergent themes in the previous section, similarities and differences between the responses obtained from the three cohorts of students will be presented in this section. Interpretations of the findings will be also discussed following each heading.

5.2.3.2.1 Uncertainty and unfamiliarity with the term clinical reasoning

When asked to elaborate on their understanding of clinical reasoning, most (fourteen out of eighteen) of the interviewees were either **uncertain** or **unfamiliar** with what the term means. Some of them admitted that this was their first time to hear about the term clinical reasoning *e.g.*

"*Well, I've never heard of the term before your research"* (B2).

"*I feel like I may be straying a little bit not knowing a proper definition of clinical reasoning"* (M1).

"Clinical reasoning?...No idea"(T5).

[8] OPG stands for Orthopantomogram. This is a panoramic view of the dental arches and the temporomandibular joints.

However, half of the respondents were able to elaborate on their understandings of clinical reasoning after the researcher had posed some probing questions such as "*when you have a patient at your dental office, how can you deal with his/her problem?... What do you need to do in order to treat that patient?"*

Four interviewees were able to provide a definition to the term and appeared to be familiar with what it implies without being probed. Three of them were from the University of Manchester and one from the University of Birmingham who referred to clinical reasoning *as:*

> *" Clinical Reasoning, so your assessment of what you think is the best option and the best way, depending on what you've looked at, to continue on for your patient and to treat your patient?"* (B4).

Even when this participant appeared not to be struggling with providing a proper definition for clinical reasoning, she appeared to be hesitating, questioning the interviewer about the accuracy of her information regarding the definition. Two of the three Manchester participants, who seemed to be familiar with the term, provided acceptable definitions reflected their fair understanding of clinical reasoning, as follows:

> *"when maybe you have a topic and you try and think through the different components of it and try and deduce what the best answer might be…So if you have a topic you might think about what investigations you might want to do, the pros and cons of each one, and then for the treatment options, the advantages and disadvantages for each treatment option"* (M4).

The third one provided a good explanation of the term, as follows:

> "*Is it weighing up things and seeing if it's good to do a certain decision and weighing it up, seeing the risks and the benefits and disadvantages of something and then seeing if you'd go for that clinical* treatment?"(M7).

However, he was still questioning the interviewer about the meaning and showing some degree of uncertainty.

None of Taibah participants was familiar with the term. One of them expressed their strong feeling of not knowing clinical reasoning as *"Clinical **what** !!!-?"* (T3). The language barrier could be a contributing factor of not knowing what is meant by clinical reasoning for the Saudi students. Students at Taibah University are taught dentistry in English as a second language.

5.2.3.2.2 Providing examples for clinical reasoning

Participants were asked to provide examples for clinical reasoning. Most of the participants have provided general examples of clinical reasoning without referring to a specific patient's case, although they were originally asked to provide examples of clinical reasoning *they had engaged in*. Some of them did not even mention a specific dental case to deal with as an example of clinical reasoning, as follows:

> *"Well, I thought we do that in day to day basis when we diagnose patients and write each treatment plan, with the help of a supervisor"* (B2).

5.2.3.2.3 Methods of learning clinical reasoning as perceived by the students

When asked about the methods of learning clinical reasoning, students provided diverse answers. Different learning methods were reported by the students. Emergent themes are presented in Figure 5:3. Although the dental school at the University of Manchester implements PBL, only some participants mentioned it as a method of learning clinical reasoning.

Most of the interviewees, a total of thirteen, considered *experience and their own work* as being the most important way of developing the skills of clinical reasoning *e.g.*

> "*and then, I think, then the real clinical reasoning comes with experience so, once you start seeing patients and seeing what... you know, you can have textbooks and you have guidelines but you've got a patient at the end of the line and receiving this treatment so we need to think about that as well"* (M7).

> "*…and then I think you have to apply it more yourself, because we don't really get taught how to apply it. It's just sort of something I find you know when you see more patients and …*" (B6).

> "…*by experience*…" (T1).

Most of the interviewees referred to *'on-clinic'* as an important method for learning clinical reasoning.

Developing clinical reasoning skills was seen as *an incremental process* as explained by three students from the University of Birmingham and two from Manchester *e.g.*

> *"Just sort of throughout the whole of dental school, sort of like… So you obviously learn from textbooks like different conditions and what the different treatment options could be and then you get different lectures about communicating with patients, and professionalism and everything, and then when you see your patients you sort of have to apply what you've learnt before, just throughout the time."* (B6).

> "*Well, it started off with textbooks really, what you're meant to do, what you're not meant to do, guidelines, and then, I think, then the real clinical reasoning comes with experience so, once you start seeing patients and seeing what... you know, you can have textbooks and you have guidelines but you've got a patient at the end of the line and receiving this treatment so we need to think about that as well*" (M7).

Experience of other colleagues or tutors was considered by two interviewees as a method of learning clinical reasoning *e.g.*

> *"When you see someone else going through that reasoning in your head and you can understand their logicality and their process of thought, that enables me a lot to go through something like that myself"* (B4).

The acquisition of *basic knowledge* was seen by most of the interviewees as being of a paramount importance in acquiring clinical reasoning skills. Eleven interviewees mentioned lectures and didactic courses as being the most important methods of learning clinical reasoning. One of the Birmingham students mentioned electronic courses, which is provided for Birmingham's students (see Chapter3), as being important. Basic knowledge obtained from text books was considered as a learning method for clinical reasoning skill by five interviewees. Knowledge coming from the review of literature was also mentioned by a few Manchester and Taibah students *e.g.*

> *"…and a little bit obviously what is says in the textbooks to back up those lectures, and then I think…"* (B5).
>
> *"You might go away and research, have a look at different papers that might have been published like systematic reviews, cohort studies, things like that"* (M4).
>
> *"…dental books or researches in the internet"* (T1).

The role of clinical tutors in acquiring and developing clinical reasoning skills was the third most common answer to the same question as perceived by more than half of Birmingham and Manchester participating students *e.g.*

> *"Well I think it's been through the experiences of other tutors. So here we get taught by people who are practitioners. So their own*

experiences, sort of they'll tell you what works for them, and if it works for them, you sort of think, 'Well it's going to work for me" (M2).

Evidence-based and inquiry-based learning was also mentioned by some of Manchester participants as an important method of learning clinical reasoning *e.g.*

"... Whilst reading a lot of books and stuff it tells you that it's really, really good for patients to rinse out with Chlorhexidine. It reduces the chance of dry socket. When I did my critical appraisal topic and looked at all the different amount of data, appraised it, had a look at it, it turns out that there wasn't a significant difference at all which helped me come to the understanding that it doesn't have a significant difference. It isn't needed. Then so when my patient asks, 'Will I need something else?'…'Yeah. We can give you perioperative use of clorhexidine', because there's no significant difference for it." (M3).

"Another way and the best way without a doubt is to look at randomised control trials and systematic reviews of studies and see what the outcomes have been. So whether it's to replace a filling or repair a filling…" (M2).

Other methods for learning clinical reasoning such as *small group learning* and *case reports* were mentioned by a few students.

5.2.3.2.4 Discussion of similarities and differences between students' understanding of clinical reasoning

After presenting our findings of how the participants interpreted clinical reasoning with examples of their scripts, we will now discuss and compare their responses. Most of the participants from the three different dental schools were unfamiliar with the term clinical reasoning with the exception of a few interviewees from the University of Manchester.

After posing probes some of the participants were able to elaborate on their understanding of clinical reasoning, but non-native English speakers were facing difficulties in working out the meaning from the term itself. As mentioned before in this research, although clinical reasoning as a term is commonly found in dental schools' documentations, there is still a lack of the deep understanding of its meaning. Despite the high proportion of the interviewed students who were uncertain or unfamiliar with the term clinical reasoning, native English speakers can still guess the meaning from analysing the words (Jin and Kling, 2009, Berardo, 2007, Boulouffe et al., 2013). This was supported by the following example of an explanation provided by one of Birmingham students in response to the question of *(what is clinical reasoning?)*

> "*Well, I've never heard of the term before your research, but what I understood is how you would reach to your diagnosis as treatment planning, and what the reasons are behind what you do"* (B2).

By looking through the definitions described by the participants after probing, Birmingham students commonly explain the necessity to decide on the best treatment option for the individual needs of the patient. They also mentioned terms like decision making, clinical outcomes and treatment planning, as follows:

"*I think with the different treatment options, deciding what the best option is for the patient, and reasoning up which is the best for the patient, and which has the best outcome*" (B3).

"*Clinical Reasoning, so your assessment of what you think is the best option and the best way, depending on what you've looked at, to continue on for your patient and to treat your patient*" (B4).

Weighing the risk and benefit and involving the patient in the decision was also mentioned by this sample of students *e.g.*

"*which treatment options fit best, and you'd have to go through like the pros and cons of each option. I guess that's sort of reasoning*"(B5).

"… *like problem solving and what decisions you make and weigh up sort of risk benefits to the patient, like professionalism and all of that sort of stuff … tied in to, yeah, to making decisions with the patient, that you think is sort of right, best interests*"(B6).

For Manchester students, clinical reasoning was mainly about weighing up the advantages and disadvantages and risk and benefits of a specific treatment option that is supported by scientific trusted evidence *e.g.*

" Is it weighing up things and seeing if it's good to do a certain decision and weighing it up, seeing the risks and the benefits and disadvantages of something and then seeing if you'd go for that clinical treatment?"(M7).

One of participating Manchester students provided an excellent explanation of clinical reasoning, as follows:

"*Clinical reasoning… Well, I think it means just basically kind of going through a full process before actually deciding on a treatment for a patient or diagnosing a patient. I'm not really familiar with the term but I think it's just about the thought process before, weighing up the pros and the cons,* *risks and benefits, taking the holistic approach so maybe thinking about different factors that affect a patient and the treatment, so social history, medical history, taking into consideration as many things as possible and then coming to a decision regarding the patient*" (M6).

However, for Taibah students clinical reasoning was no more than how to effectively diagnose specific dental problems through their signs and symptoms, or other diagnostic aids such as radiograph and laboratory test. There was no mention of the patient specific needs *e.g.*

"... I think clinical reasoning... Causes of disease or something like this. Some symptoms or sign of the disease or..." (T1).

When they were asked to provide examples of clinical reasoning they have been engaged in, only three participants gave examples of clinical reasoning reflecting on real patients they have been engaged in providing managements for their dental problems. Those participants, who showed good reflection and connection to what they were practicing in clinics, were from the University of Manchester. One of Birmingham students referred to a specific case presented in a lecture by saying:

" *So, for a patient maybe who - one we just did in the lecture downstairs where there was a patient who had a seven that may have been helped to a denture, but really had a lot of perio disease and*" (B1).

Two interviewees from each of the three schools discussed managing general examples of dental conditions as being examples of clinical reasoning *e.g.*

"*blood pressure test before extraction or… for example if it's above 180 I will not do extraction...*" (T3).

Eight out of the eighteen participants have provided general examples of clinical reasoning without referring to specific conditions or patients showing a low degree of reflection on what is taught and practiced during the course *e.g.*

"*Well, I thought we do that in day to day basis when we diagnose patients and write each treatment plan, with the help of a supervisor*" (B2).

Although the University of Manchester implements PBL in the undergraduate curriculum, some students (three out of eight interviewees) did not mention PBL as a method of learning clinical reasoning. Almost all the participating Birmingham's students appreciated the importance of clinical experience in the development of their clinical reasoning skills. However, less than half of the Manchester students and only one participant from Taibah University mentioned the role of clinical sessions in fostering the development of clinical reasoning.

Lectures were mainly considered as a method for learning clinical reasoning. Those who did not mention lectures as a source for fostering the development of clinical reasoning were mostly from Manchester. This could be a result of the PBL curriculum in which little focus is given to lectures.

The importance of tutors' role in the development of clinical reasoning was mentioned by some participants. However, none of Taibah students have mentioned the role of tutor as being important to enhance the development of this skill.

Uniquely, four interviewees from the University of Manchester mentioned Evidence-Based and Inquiry-Based Learning as being important in fostering the development of clinical reasoning skills. This might indicate the effectiveness of these teaching strategies incorporated in this particular curriculum. Please refer to Chapter 3 for more description of the different curricula of the three schools at which the study was conducted.

5.2.3.3 Comparison between the different students' samples regarding their reasoning processes when dealing with clinical vignettes

We discussed the thematic analysis of the first topic *i.e.* students' understanding of clinical reasoning in the previous section. After presenting the results of the thematic analysis (in the emergent themes section) regarding the second topic area *i.e.* students' reasoning processes, a more detailed analysis will be provided here. This analysis will be followed by a discussion regarding the differences in the reasoning processes used by the three groups of students.

A real dental case was presented to the participants in the form of power point ® presentation. Patient's information was described by the interviewer, and the participants were asked to think-aloud and describe the dental problems of that patient and go through dental managements. Another two vignettes of the same patient were also presented.

The presented patient had a remaining root under a healed extraction site. The other pathology was a condition known as Lichen planus (a white lesion on her cheek mucosa). This was in addition to other problems including dental caries and orthodontic issues of mal-alignment in the lower anterior teeth.

First, the interviewer presented medical and dental histories of a female patient stating her age, ethnicity and her chief complaints. Then another slide followed which had views of frontal, upper and lower dental arches. At this point, the interviewees were asked to think-aloud and describe the dental problems of the patient.

In the following section each vignette will be discussed separately in the same sequence presented in Table 5:1 with the areas of interest illustrated in Figure 5:4. Then common themes will be discussed with the description of the similarities and differences between the three students' samples.

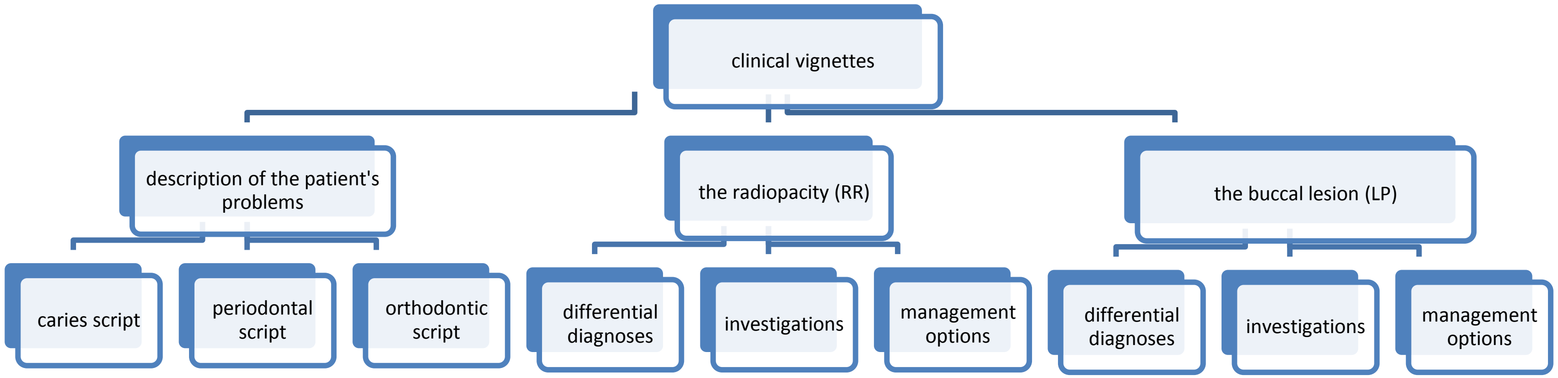

Figure 5:4: The clinical vignettes used for the interviews. Firstly, the participants were asked to describe the dental problems of the presented patient while viewing images of the dental arches. During the second vignette the interviewees were asked to describe their action while viewing a periapical radiograph of a radiopaque lesion in the maxillary arch. Finally, they were provided with an intraoral photograph of the same patient showing a white lesion in her buccal mucosa.

5.2.3.3.1 Vignette 1

Participants were asked to describe the dental problems for the presented patient. Intraoral views of the patient's dental arches and a frontal view were presented during the discussion. Radiographs were provided if required by the interviewee. Participants were supposed to discuss the condition of the soft tissues, carious lesions, and some visible orthodontic problems.

5.2.3.3.1.1 Ritual reasoning

Traditionally, dental students are taught to manage dental cases considering different phases beginning with taking medical and dental histories, examining the patient, collecting more information if required from different diagnostic aids *e.g.* radiographs. The following phase is to provide a treatment plan followed by management and providing treatment.

Examination of the patient usually starts with examining the extra-oral features of the patient, followed by examination of the gingiva and periodontal and soft tissues. Then, examining the dentition is the next step.

The management phase is further divided into well-known phases of treatment planning summarised as follows: 1) phase 1 includes managing acute symptoms, control active pathological lesions, general caries control, plaque control, pulp extirpation if required. 2) Phase 2 includes evaluation of phase 1, definitive periodontal treatment, and completion of endodontic treatment. 3) Phase 3 is concerned with providing final restorations, crowns, bridges or removable dentures. The last phase is the maintenance phase (Balshi, 1981, Villarroel, 2004, Sivakumar et al., 2012).

Going through these special protocols in their orders is not only common in dental students, but dentists also apply them in practice. This has been described by Khatami (2011) as *ritual* *reasoning* which is a common practice in dentistry. It has been suggested that the extensive use of the well-known protocols by dentists may limit the desire to search for new knowledge, which in turn anchor the old habits and procedures at the expense of scientific advancement (Glick, 2011).

When discussing the clinical case nearly all the interviewees from Birmingham and Manchester Dental Schools have followed that systematic approach to deal with the dental case. Some students have done charting of teeth in the same way a dentist would do *e.g.*

> *"Starting from the right side, we've got like the eight. Seven's missing. Six. Five is missing. Four, three, two, one. One, two, three. Four is missing. Five. And then six and seven maybe are missing. You've got the eight. Those teeth are not restorable. So they are sound teeth. The lower-arch got some decayed teeth and fillings as well, but none of the teeth on the lower arch are missing. Oral hygiene seems good. Soft tissues look fine and yeah…"* (M5).

Only two interviewees from Taibah School have followed the ritual approach, despite that one of them has clearly mentioned that this was what had been taught, as follows:

> *"first of all I will begin with a protocol that we use to do. First of all I will introduce myself to the patient. After that I will ask the patient about history and their chief complaint … after we finish the medical history and dental history, I will start with a clinical examination of the patient and I examine the gingiva and the tooth… I will start by preventative treatment - brushing, scaling, root planning After that I will do endodontic treatment if she needs or restorative treatment, composite or - after that I will do the prosthesis in phase 3. The patient needs implants or fixed prosthesis. After that, I will go for maintenance Phase 4"* (T4).

In contrast to most of the participants from Manchester and Birmingham, more than half of the participants from Taibah School did not mention the protocol of ritual when they discussed the clinical case.

One of the findings of Khatami's (2010) research indicated that although ritual reasoning was common for her students' sample, many students felt that it was unnecessary and time consuming to go through the systematic approach. Participants in the current study may also felt the same. However, this feeling was expressed mainly by the male sample at Taibah University, who did not go through the ritual reasoning possibly because they did not feel it was important to do so.

5.2.3.3.1.2 Periodontal script

As mentioned earlier, colour and appearance of gingiva around the teeth are the required visual cues to trigger periodontal scripts in dental students. Any deviation from the normal appearance of the healthy gingival tissues would then require further assessment of the disorder *e.g.* measuring the pocket depth and the bleeding index.

All the interviewed Birmingham students were able to describe the condition of the periodontal tissues by just looking to the presented frontal view. Three of Taibah interviewees mentioned the condition of gingival tissue when they were asked to discuss the dental case. Surprisingly, only three out of the seven interviewed Manchester's students assessed the condition of the gingival tissues by pattern recognition, and one of the students reported that he needed more investigations to evaluate the periodontal condition, as follows:

> "*Okay. So first of all we need to address that although she says that she brushes her teeth twice a day etc., we need to assess that*

for ourselves. So do a thorough plaque and bleed BP plaque and bleeding scores" (M3).

Periodontal scripts is considered to be common in dental students (Khatami et al., 2011). All participants from Birmingham tended to be careful and followed the ritual in dentistry. They were able to elaborate and mention the condition of the gingival tissues when they started to discuss the case using periodontal scripts. Three out of the five interviewed students from Taibah University and a few participants from Manchester University mentioned the periodontal condition of the patient. This might be because the patient had almost healthy gingival tissues and no obvious gingival inflammation or swelling which triggers the discussion of periodontal health.

5.2.3.3.1.3 Orthodontic script

Dental students mainly detect orthodontic problems *e.g.* mal-alignment and cross bite by their appearance. They may request further investigations afterwards.

Most of the interviewed students from the three dental schools were able to assess the orthodontic condition of the patient by pattern recognition *e.g.*

"*She has crowding in lower arch, she has aesthetic problem in upper teeth and rotation - that rotation in lateral incisor little bit and the occlusion is not that - not good. She has edge to edge occlusion*" (T5).

However, one of Birmingham's and two of Manchester's interviewees did not mention any orthodontic problems.

5.2.3.3.1.4 Caries script

Caries is the most common disease of teeth. As described by Khatami (2010), most dental students can diagnose carious lesions from their colour and appearance. Almost all the participants were able to detect carious lesions from looking to the views of upper and lower arches. However, two of Birmingham's interviewees mentioned that they needed to investigate more before they can decide whether these were actually carious lesions or not *e.g.*

> "*… Obviously you've charted where the caries are now, and you know which teeth are carious, so then you'd fill in the carious teeth, you'd then sort them out. You'd hopefully… You would have done x-rays as well, and special tests beforehand –bitewings*" (B4).

5.2.3.3.2 Vignette 2 (the radio-opacity/ the remaining root)

The interviewer then showed the participants a peri-apical radiograph of the upper left first molar of the same patient and asked the following question:" *Do you see this radio-opacity? What do you think it might be?".* As presented in Figure 5:5, the researcher was focussing on some areas when making the comparisons between the participants from the different dental schools. These areas were: the accuracy of diagnosis, the reasoning processes used to make diagnoses, ability to provide clinically related differential diagnoses, and the decision analysis used by the participating students. These areas will be discussed in the following sections.

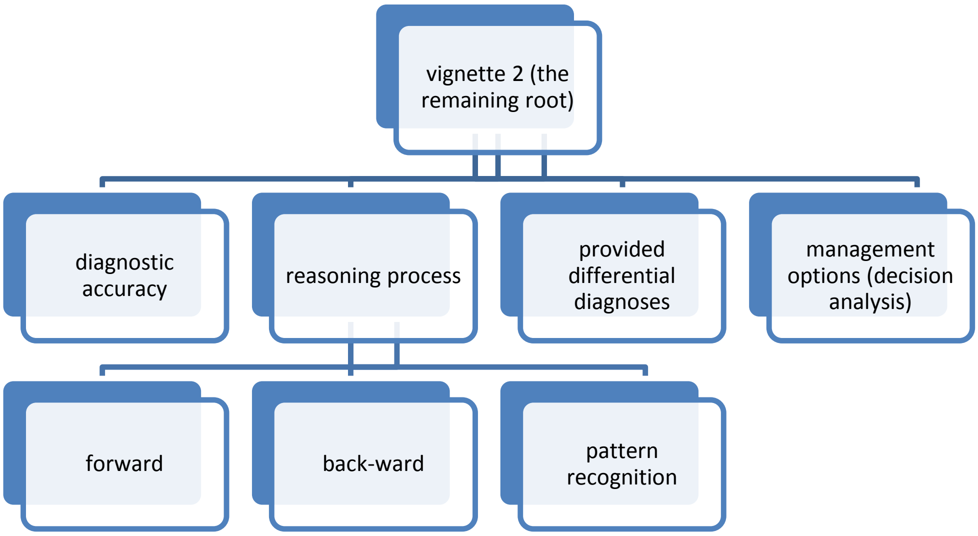

Figure 5:5 Areas of concern and the emergent themes when making the comparison between the three groups of student regarding the second vignette.

5.2.3.3.2.1 Accuracy of diagnosis

Most of the students were able to correctly diagnose the radio-opacity in the maxilla as a retained root, although the root was not well defined by lamina dura and the gingiva had healed over it. However, two participants, one from Taibah and the other from the University of Manchester, were not able to get the right diagnosis *e.g.*

> *"…because well the roots, they're more defined aren't they. There's a better outline of it unless it's become- I'd probably get a second opinion. If I'm unsure I would get a second opinion. Right now I'm unsure what that is"* (M3).

> *"Actually we need to go for more investigation. Maybe we need a biopsy or something. I can't get a definitive. ..Maybe odontoma or osteoma."* (T4).

One of Birmingham students changed her mind about the right diagnosis of the retained root. She had picked the right diagnosis of the radio-opacity by pattern recognition on the first place. Then she said:

"*It doesn't look as clear cut as a retained root to me. It's not circumscribed enough"* (B1).

One of Manchester participants also changed her mind about the right diagnosis of the radio-opacity. She had correctly diagnosed the lesion through backward reasoning. She then changed her mind being uncertain and admitted the need for a second opinion, as follows:

"*Okay. To me that looks like it's a retained root. Maybe the six fractured when they were doing the extraction…Ask the patient if they know about a root that might have been retained in the past. I could ask my colleagues as well to see if I can get a second opinion. Check in the mouth to see if I can't find any retained root intra-orally….It could be a retained root. It could be an odontome or it could be some other sort of bone swelling."* (M4).

Two of Manchester's and most of Birmingham's interviewees mentioned that they needed to carry out more investigations in order to formulate their final diagnosis of the radio-opacity *e.g.*

"*But you would have to investigate further as to what the problem actually is. I don't... I can't really hazard a guess*" (B1).

About half of the interviewed Manchester students admitted their need for consultation and getting a second opinion mostly due to their lack of experience *e.g.*

" In my lack of experience as a dentist, it's not something that I've seen before in its form like that because it's got a very corticated margin. So I'd get a second opinion from someone with a little bit more experience" (M1).

Almost all Manchester participants requested more information in order to reach their diagnoses *e.g.* more radiograph views *e.g.*

"Yes, I would review the periapical[9]*"* (M7).

5.2.3.3.2.2 Clinical reasoning processes used by the interviewees to diagnose the radio-opacity in the maxilla

As mentioned earlier, students used different reasoning strategies to diagnose the radio-opaque lesion in the second vignette. These strategies were: pattern recognition, forward (inductive), backward (deductive), and combination of both forward and backward reasoning. The following section will describe the reasoning strategies used by the participants when they discussed the remaining root in the presented case. Examples will be discussed for each strategy.

5.2.3.3.2.2.1 Diagnosing the radio-opacity as a retained root using pattern recognition

Regarding the second vignette, some students were able to correctly provide a diagnosis using pattern recognition. They were mainly looking for a radio-opacity degree matching the tooth structure and the presence of lamina dura around the root giving it a well-defined outline. About half of the participants used pattern recognition to correctly diagnose the retained root *e.g.*

"*Okay. Yeah. It seems to me that's a retained root. Yeah*" (M5).

5.2.3.3.2.2.2 Diagnosing the remaining root using forward reasoning (inductive)

As mentioned earlier, forward (inductive) reasoning is a process in which the student uses the patient's information and work through

[9] Periapical radiographs are used to view crowns and roots of the teeth

the given data and criteria to reach a specific hypothesis and diagnosis. The results of the thematic analysis of the current study showed that only one student, who was from Manchester, used this process to diagnose the radio-opacity, as follows:

> " *There's a radio-opacity about one to two centimetres in diameter which is obviously some form of dental tissue. Things it could be would be a retained root potentially*" (M1).

5.2.3.3.2.2.3 Diagnosing the remaining root using backward reasoning

Backward or deductive reasoning is when the student suggests hypotheses and work through them to either accept or reject them. It is often the characteristic of students (novices) reasoning. About half interviewees used the backward reasoning while diagnosing the remaining root *e.g.*

> " …a root…*because what I'm looking for is like a lamina dura around the roots, but you would see… But with all the radiolucency you can see all around, that's a bit unusual for a root to have that, but it was an edentulous space in the photograph, so what else could it be?"* (B2).

> *"…it could be there's a retained root that has healed over, maybe if there was an extraction and it wasn't completely removed possibly"* (M6).

> *"…a remaining root…Due to extraction. Maybe fracture due to... It's a complication of extraction. Maybe fracture. The root may be fractured"* (T1).

5.2.3.3.2.2.4 Combination of inductive and deductive reasoning

Only one participant used a combination approach to diagnose the remaining root. He was a student at the University of Manchester, as follow:

> "*So I'd palpate there and I'd feel if I can feel any unusual protuberance or anything like that. I mean it could be a retained root from a previous extracted tooth although I can't really see*

much canal root anatomy. So I'm not sure whether it is a retained root or not, but it's likely to be one" (M2).

5.2.3.3.2.3 *Ability to provide differential diagnoses*

Only two interviewees have provided differential diagnoses to the remaining root. Both have used the backward strategy to diagnose the lesion. These were presented, as follows:

"*it might be … a cyst of some kind, because it is quite large, and obviously with a cyst it wouldn't exactly be there, it would be a bit higher up*" (B3).

" *It could be an odontome or it could be some other sort of bone swelling*" (M4).

5.2.3.3.2.4 *Deciding on the management options (decision analysis)*

In case of managing a remaining root different options are available. Regarding dealing with the current case, in my personal opinion as a dentist, I would check the cause of extraction in the first place. If the extraction was done as a management for a badly decayed non restorable tooth, I would expect the remaining root to be infected.

The presented dental history of the patient indicated that she had multiple extractions in the past due to caries. The radiograph showed that there was also some widening in the lamina dura around the apex, although not easily detectable. This would further support the possibility that the remaining root could be infected. This remaining root was big, more than half of the original root size. Despite the fact that the area was asymptomatic and the gingiva looked healthy and healed very well over the extraction site, there is still strong evidence of possible infection. So, extraction would be the wise option to do before replacing the missing teeth in order to address the patient chief complaint as wanted to replace her missing teeth. This is of course should be suggested by the dentist and explained in details to the patient, and never done without patient's consent.

When it comes to the replacement of the missing teeth, many options are available such as implants, fixed or removable prostheses. The choice depends upon many factors including assessment of the patient condition and her oral hygiene and functions, financial aspects, and the patient's preference and expectations.

Students' responses varied when they discussed their management options for the remaining root and providing reasons for their choice of management. More than half of the participating Taibah students suggested the option to extract the remaining root without discussing any reason behind their choice. Only one of them explained the reason that made him decided to extract the remaining root as follows:

> "*If I'm going to put prosthesis, I have to remove it. I cannot put my prosthesis over the remaining root; I have to remove it. If I'm going to leave this base as it is, I think if it is asymptomatic, no problems, not infected, not carious, I'll just leave it for a while at least. Finally it should be removed at the end of the day, yeah*." (T5).

However, none of Taibah participants mentioned the role of the patient in decision making. All the participating Birmingham and most of the Manchester participants gave reasons for their choice of management regarding the conditions of this special case *e.g.*

> "*a denture or even bridge work if her perio is up to scratch, but it's quite long spanning edentulous areas so maybe because she's got multiple it might be better to put a denture in*" (B1).

"*Yes, because if she chooses to have a denture then it's good to keep the retained root if it's not infect, because it keeps the bone, stops it from resorbing but if she's going to have a bridge, and you're going to extract it, you have to wait at least three months before you can give the bridge*" (M7).

One of Manchester students admitted that he needed to take a second opinion due to his lack of experience, as follows:

" *Well I think having a retained root that close to the surface, again this is slightly outside of my experience. So I'd definitely be getting a second opinion on this, but in the situation that I'm in where I don't have the extra experience and second opinion, I'd be thinking that if the root had been a lot deeper*"(M1).

More than half of the participants from Manchester and Birmingham described the importance of patient's involvement in deciding upon management options.

5.2.3.3.3 Vignette 3 (the white lesion in buccal mucosa/ lichen planus)

The third vignette for the same patient discussed a white lesion in the buccal mucosa known as *lichen planus*. This lesion is one of the white lesion varieties affecting the oral mucosa, and can be easily misdiagnosed and mixed up with other white lesions of the oral cavity such as oral candidiasis (Tyldesley, 1974, Parashar, 2011).

The interviewer asked the following question: "You then discovered this lesion on the buccal mucosa of the patient. The lesion was asymptomatic and bilateral. What do you think it might be and how can you manage it?" In the following section, the participants' responses were discussed in the same way the previous vignette was discussed starting with the accuracy of diagnosis followed by the different reasoning processes used by the participants, and finally a description of their decision analysis.

5.2.3.3.3.1 Accuracy of diagnosis of lichen planus

All of the interviewed students at the University of Birmingham were able to correctly diagnose the white lesion as lichen planus. Four out of the five interviewed students at Taibah University were also able to make the correct diagnosis. However, only two participants from the University of Manchester diagnosed the lesion as lichen planus, and one was hesitant to provide a diagnosis. One of the Manchester participants admitted the need to get a second opinion, as follows:

> *"… and again get a second opinion from a more experienced colleague if there wasn't one available*" (M1).

All Manchester participants, two from Taibah and two from Birmingham mentioned that they need to do more investigations to reach an acceptable diagnosis *e.g.*

> *"…but you would rub against it, see if any of it comes off. Ask them if it's changing? Ask them if there are any changes. If it has had some changes, then you potentially do a biopsy"* (B4).

> *"Okay. First of all I would look around in the mouth to see if there is any like restorations and then I'll take a history of the lesion. See if it's like tender or she's having any pain from it. Anything that*..." (M5).

> "*Actually we need to go for more investigation. Maybe we need a biopsy or something. I can't get a definitive*" (T4).

5.2.3.3.3.2 Clinical reasoning process used by the interviewees to diagnose the white lesion in buccal mucosa

This section will discuss how the participants reached their diagnoses and the clinical reasoning strategies they used.

5.2.3.3.3.2.1 Diagnosis of the white lesion in the buccal mucosa as lichen planus using pattern recognition

Half of the interviewees from Birmingham and one from Taibah made the correct diagnosis using the pattern recognition process of clinical reasoning *e.g.*

> " *So, it looks like it's white, like striated pattern, so, I know it's ridiculous but it looks like Lichen Planus*" (B5).
>
> *"Yes Lichen planus"* (T5).

5.2.3.3.3.2.2 Diagnosis of the white lesion using forward (inductive) reasoning

Only one participant, who was from Taibah used forward reasoning strategy to make his right diagnosis of the white lesion as lichen planus, as follows:

> *"…By scratch the lesion. if it comes or not, Just that…lichen plannus?"* (T3).

Another participant also used this reasoning approach, although he was not sure about his diagnostic decision, as follows:

> *"Painless. So striated bilateral white lesion. Very large…With my finger I'd try to wipe it off because there's obviously a differential diagnosis of white lesions. Things I'm going to be thinking of is candida infection. Also lichen planus. Lichenoid reactions and things like that, but I wouldn't be able to form a diagnosis because in order to differentiate these lesions you need to have special tests like biopsies and things like that. So my immediate management of this would be to obviously wipe off because that can give*

information about candidal infections and again get a second opinion from a more experienced colleague if there wasn't one available. But my gut instinct is that because it's bilateral in its appearance, that I would suggest that it's lichen planus, but that would be a very tentative provisional diagnosis. I would do a referral letter to a regional oral medicine department nearby" (M1).

5.2.3.3.3.2.3 Diagnosis of the white lesion via backward (deductive) reasoning

A few interviewees used the backward strategy to make their diagnoses *e.g.*

"It could be lichen planus, because it looks … it is quite white and it is striated, and it is bilateral, it is usually a sign of lichen planus. It could be some other form of leucoplakia, but if it is asymptomatic, because lichen planus usually is asymptomatic, I would probably say it is lichen planus" (B3).

One of the Manchester participants used this type of reasoning when discussing the third vignette, although she did not make the correct diagnosis for the lesion, as follows:

"…It can be traumatic from biting the cheeks. Could be a Lichenoid reaction to amalgam or gold, but I couldn't see any gold in her mouth. Could be lichen planus. So we need really to take a full blood count…" (M5).

5.2.3.3.3.2.4 Diagnosis of the white lesion using combination of forward and backward reasoning

Only one participant used the combination process to correctly diagnose the lesion, as follows:

"According to the given criteria, mostly it's considered a Lichen planus. I think it Wickham striation [10]the... and the bilateral of the condition consider it as lichen planus" (T1).

Although most of the participants from Manchester did not make the correct diagnosis for this lesion, three of them used a combination approach when they discussed the possible diagnoses *e.g.*

"Okay. So it could be just frictional keratosis, it could be – if it's been there all the time then maybe it's just …Maybe – if it wipes off then it might be candida. If it didn't… are there any – are there white patches anywhere else maybe, but I'm not sure …" (M6).

5.2.3.3.3.3 *Ability to provide differential diagnoses*

Although most of the Manchester participants did not make a final diagnosis, most of them were still able to provide an acceptable range of differential diagnoses for the lesion *e.g.*

" You'll probably come up in your head with differentials of white lesions in the mouth. So in your head you've already got ideas of lichen planus…Possibly Lichenoid reaction…Possibly some pseudomembranous candidiasis as well" (M3).

5.2.3.3.3.4 *Deciding on the management options (decision analysis)*

Most of the participants from Birmingham mentioned that they need to investigate about the possible causes of the white lesion and manage the case accordingly *e.g.*

" And maybe there's precipitating factors in that stress I think can be a factor sometimes, so you try and find out any precipitating factors that she has got, maybe drugs that she's taking, anything

---

[10] White striation also known as Wickham striae are characteristic features of striated lichen planus

that she could maybe – if her stress levels are high, maybe try and reduce her stress levels, it might help it to go away. " (B1).

Some of the Birmingham and one of the Manchester participants acknowledged the pre-malignancy chance of the lesion and suggested that they should follow up the lesion regularly for possible changes which could be malignant *e.g*.

"… *so if it's asymptomatic, she's not worried about it, generally you just need to advise the patient of any risk of malignancy, which is like quite low, it's like 1%. You tell her that although it's rare for the population; it's 1% of all medical conditions; it's actually fairly common, although it's rare in the population*" (B5).

A few participants mentioned the need to inform the patient about the lesion and the possibility of malignant changes in the future addressing the published evidence behind their decision. Those participants were from the University of Birmingham. However, one of the participants from Manchester preferred not to mention the possible chance of malignant development to the patient since the lesion is currently asymptomatic, as follows:

"I wouldn't say this to the patient but I am aware that there is a risk of malignant change but it's not something that I'd say to the patient at this stage" (M1).

5.2.3.3.4 Discussion of the similarities and differences between the three students groups in their reasoning processes

Clinical vignettes regarding one patient were discussed during the interviews. The participants responded in different ways during the discussions. Analysis of their responses revealed some similarities between the participants from the three curricula. Periodontal, orthodontic and caries scripts were common among the participants. Ritual reasoning was common among the UK participants but not among Taibah interviewees. This might be related to the fact that these participants tried to keep the conversation, with the female interviewer, short due to the religious barriers characterising their culture.

The reasoning processes used by the interviewees were different when they discussed the different clinical vignettes. In general forward reasoning was the least common strategy used by the samples. It is argued that this process is uncommon in students, and experts commonly use it to diagnose difficult clinical cases (Elstein, 2009, Eva et al., 1998, Higgs and Jones, 2008b). Two participants from Manchester and one from Taibah actually used inductive (forward) reasoning when they discussed the clinical vignettes.

Nearly half of the participants from the three groups used pattern recognition to correctly diagnose the remaining root. This might indicate that diagnosing the remaining root might be not difficult for the final year dental students. This argument can be supported by the fact that most of the participants were able to make the correct diagnosis for the radio-opacity mainly by using pattern recognition. Combination reasoning was uncommon among the participants when they discussed this vignette.

Regarding the diagnosis of the white lesion in the buccal mucosa, a large number of Manchester participants failed to provide the correct diagnosis. Most of them provided acceptable differential diagnoses. This result might support what is known about the difficulty of diagnosing this lesion (Tyldesley, 1974, Parashar, 2011). However, all Birmingham and most of Taibah participants were able to provide the correct diagnosis using different reasoning processes, but they asked for more information and required more investigation.

The need to get supporting opinions was common among the PBL (Manchester) sample. This might be caused by the teaching strategy used at this school in which students usually work in their groups to solve clinical cases. Taibah participants did not mention the role of the patient in making clinical decisions. This can be related to the cultural characteristics and the health care system in SA. A more detailed discussion will be provided in the global discussion section.

5.2.3.4 Comparison between the different groups regarding the length of the interviews

In addition to the above discussed comparison between the three different groups of students regarding the two major topic areas, another element will be added here. This involves comparing the time spent during the interviews. This time was indicated by the length of audio- recordings obtained by using a digital recorder. As mentioned earlier a mixed methodology was used for the current research. Although the current study was qualitative in nature, a quantitative data analysis was useful to understand the differences between our samples. Mean values of the interviews duration were calculated as presented in Table 5:2. Box plots were presented in Figure 5:6 to illustrate the time spent by each cohort.

Table 5:2: Mean values for the time spent during the interviews. Manchester participants spent more time followed by Birmingham and finally Taibah participants

School	**N**	**Mean of time spent in min.: Sec.**	**Std. Deviation**
Birmingham	6	9:49	1:52
Manchester	7	11:20	3:25
Taibah	5	8:04	0:36
Total	18	9:55	2:39

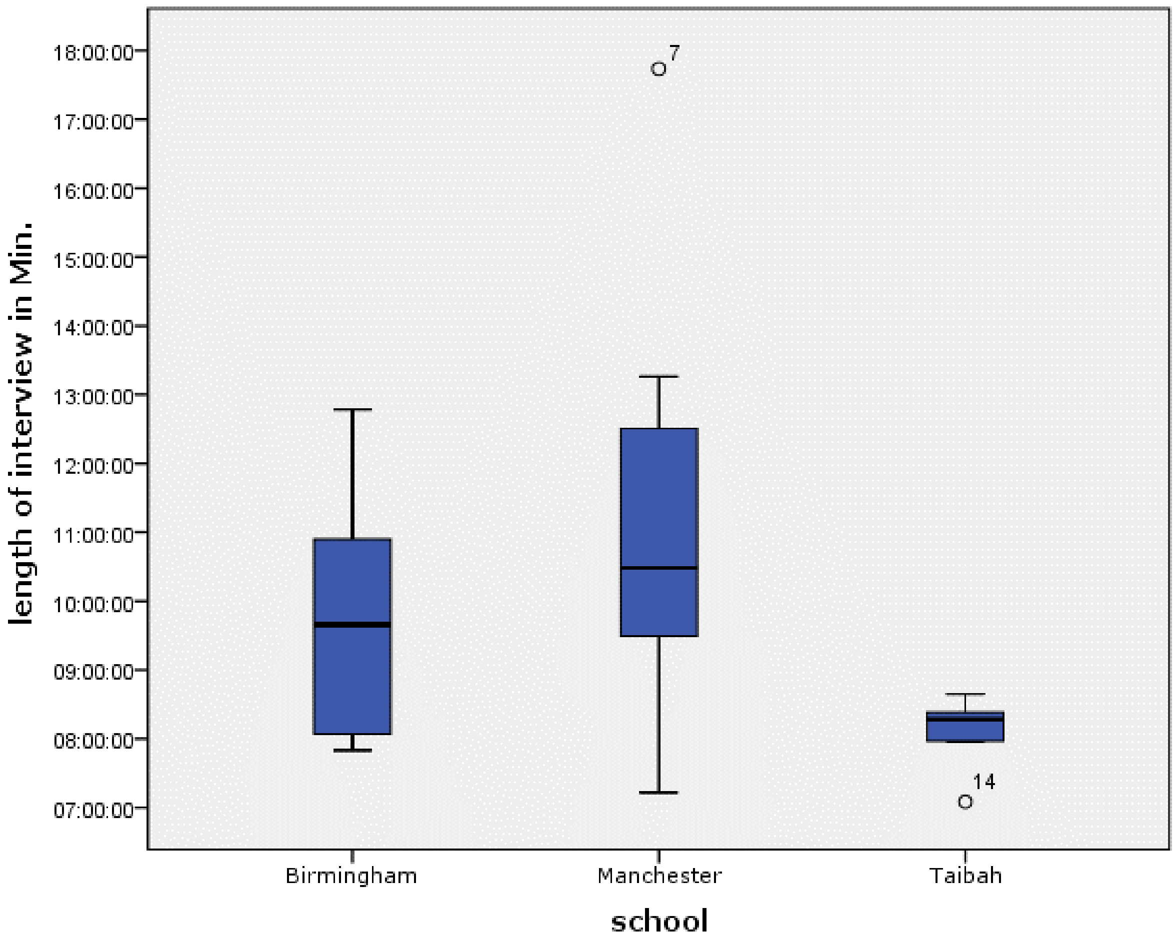

Figure 5:6 Box-plots illustrating the difference in the length of interviews for each cohort in minutes, showing that Taibah participants spent less time during the interviews compared to the other two cohorts

Manchester participants spent more time when they discussed the research vignettes compared to Birmingham and Taibah participants. The mean values for the length of interviews were 9:49 minutes for Birmingham, 11:20 minutes for Manchester and 8:04 for Taibah participants.

5.2.4 Global discussion

In the previous sections we presented the results of thematic analysis and discussed them separately in each major topic area. In this section a discussion of what was presented in this chapter and its relation to the literature will be provided.

In the past, qualitative methods have not gained prominence in medical and dental education research. This was mainly due to its unclear nature and the lack of proper explanation of its process. However, health care research is now more inclined to use mixed methods involving the qualitative and quantitative methodologies (Pope and Mays, 2006). The use of a mixed method is suggested to add more value to the research and a rigorous understanding of the phenomenon in question (DiCicco-Bloom and Crabtree, 2006). In the current research a mixed method was used to get a deep understanding and reveal the lack of clarity surrounding clinical reasoning in dental students. The current study represents the qualitative part of the research.

In order to get a deep understanding of the clinical reasoning process and the possible effect of the different types of curricula, an interpretive approach was used in a thematic analysis of semi-structured in-depth individual interviews. Information processing theory was the conceptual framework used for the current study. By using the think-aloud and the verbal probe methods we were following the principles of information processing theory (DiIorio, 2006). The think-aloud method is claimed to be an effective way to access the cognitive processes used in clinical reasoning and problem solving tasks (Simmons, 2003, Newell and Simon, 1972, DiCicco-Bloom and Crabtree, 2006).

In the current study we aimed to compare the results obtained from the three cohorts of final year students reflecting the possible effect of the curriculum models. Table 5:3 on page 320 summarises the main similarities and differences between them.

Students' understanding of clinical reasoning was the first major topic area studied. High levels of unfamiliarity and uncertainty about what clinical reasoning means were common features among the participants. Despite the high proportion of interviewed students who were uncertain and unfamiliar with the term clinical reasoning, nevertheless native English speakers can still guess the meaning from analysing the words (Jin and Kling, 2009, Berardo, 2007).

Four interviewees were able to provide a definition for clinical reasoning, without being probed, and appeared to be familiar with what it implies. Most of them were from the University of Manchester and one from the University of Birmingham.

Characteristics of the undergraduate curriculum and the educational background have been shown to have an effect on the development of clinical reasoning skills. This effect is suggested to persist and carried out through the dentist's life affecting his/her decision making (Balto and Al-Madi, 2004). Furthermore, Bowen (2006) claimed that knowledge is organised in students' mind in the same way as it has been taught. In clinical settings the recall of basic knowledge might be slow or absent because students need to connect this basic knowledge to the real cases seen in clinics.

Looking through the definition of clinical reasoning described by the participants, Birmingham participants have commonly explained the necessity to decide on the best treatment option for the individual needs of the patient. They have also mentioned terms like decision making, clinical outcomes and treatment planning. Weighing the risk and benefits and involving the patient in the decision have also been mentioned by those participants. Their response can be related to a specific feature of their curriculum. There is a special course provided at Birmingham Dental School known as e-course in which students can access a discussion of a large number of different clinical cases. Diagnoses and management options for these individual cases are also discussed in this course.

For the Manchester participants clinical reasoning was mainly about weighing up the advantages and disadvantages and risk and benefits of a specific treatment option that is supported by scientific trusted evidence. This may reflect the strategy used in the PBL learning in which students focus on signs and symptoms of a disease trying to work through differential diagnoses, do their research and come up with different management options.

For Taibah participants clinical reasoning was no more than how to effectively diagnose specific dental problems through their signs and symptoms, or other diagnostic aids such as radiographs and laboratory tests. There was no mention of the patient specific needs. This finding could reflect some cultural characteristics as most people in Saudi Arabia have a high trust in dentists' decisions. Furthermore, this attitude may be influenced by the fact that most native Saudi dentists work for the government sector which provides free dental treatments in which the client has a minimal role in discussions about the treatment options available. However, these interpretations are suggested by the researcher being a native Saudi dentist. Obviously, more research is required to study the cultural impact on the dentist' clinical decisions.

The traditional separated phases of dental curricula *i.e*. pre-clinical and clinical phases showed a possible effect in reducing the level of reflection among students, especially in case of the non PBL-curricula when the participants discussed examples of clinical reasoning. Type of assessment can also affect the students' behaviour when dealing with clinical cases.

Clinical reasoning was commonly taught in case-based presentation focussing on generation of differential diagnoses and working on these to reach the final acceptable diagnoses (Thomas, 1992, Menahem and Paget, 1990). Commonly, medical schools teach medical history-taking and communication skills in the preclinical phase of the undergraduate study, while relaying on clerkships to provide instructions for clinical reasoning. As a result of this separation, students may not feel the important connection between communication and obtaining good medical information, not appreciating the impact of reasoning on communication, or even undervalue the psychosocial patient history (Windish et al., 2005).

As mentioned earlier, the role of curriculum on the development of clinical reasoning skills is not clear (Goss et al., 2011) and there is a lack of empirical data which supports the superiority of clinical reasoning skills developed in PBL compared to traditional curricula (Colliver, 2000). However, our results showed that when the participants were asked to give examples of reasoning they were engaged in, only three participants mentioned examples of real patients they have been engaged in providing a management for their dental problems. Those participants were from the University of Manchester, who were taught in a PBL curriculum rather than the preclinical/ clinical model implemented in the other two schools. Nearly half of the participants provided general examples of clinical reasoning without referring to specific conditions or patients as an example.

It appeared that students were not commonly using their personal experience to reflect on their understanding of clinical reasoning and there might be a lack of integrating the clinical part with the knowledge base.

Although the University of Manchester implements a PBL undergraduate curriculum, some students did not perceive the PBL as a method of learning clinical reasoning. Most of the interviewees stated that experience and their own effort and work are the most important ways of enhancing their clinical reasoning skills as well as acquiring sound knowledge base mainly from didactic courses. Sackville (2008) argued that many academics still prefer providing information to their students via traditional lecturing; our results found that students also perceived lectures as effective methods of learning clinical reasoning. The only participants mentioned (EBL) and (IBL) were from Manchester. It would be necessary to enhance the importance of (EBL) and (IBL) as a method of fostering the reasoning skills.

As mentioned in Chapter 2 dentists' decisions can be influenced by consultation with other staff, as they consider it a source for information used during decision making (Straub-Morarend et al., 2011). Similarly, some of the UK participants considered that consultation with staff members or other students was a method for learning clinical reasoning.

Taibah participants barley mentioned the role of tutors in developing their clinical reasoning skills compared to the other two groups. This finding may suggest a minimum role of clinical tutors. To address this finding more research is needed as will be described in the limitation section.

The second topic area in the current study dealt with the types and strategies used by the participants when they discussed the clinical vignettes. When the participants discussed the clinical vignettes, our research findings supported the suggested framework of clinical reasoning in dentistry (Khatami et al., 2011). Similar findings suggested the commonly nonlinear action of discussing the case mixing diagnoses and treatment planning. The reasoning strategy varied depending on the case presented and individual students have used different strategies when dealing with different scenarios.

Another finding was also consistent with the literature regarding the use of ritual reasoning as a common feature for reasoning in dentistry. Although ritual reasoning is a well-known characteristic of dental students (*ibid*), only two interviewees from Taibah School have followed the ritual approach. This might be due to cultural factors which dominated the interviews making the participants rushing towards providing a diagnosis and treatment without much elaboration through unnecessary talks, as the researcher was a female and all the participants were male. The main feature characterised these participants was that all of them appeared to feel like being examined for the accuracy of their information and almost all of them had checked their answers with the researcher at the end of the interviews. That could be a reflection of their assessment system which is dominated by the summative approach and the deficiency of the formative assessment in this particular curriculum.

Caries, periodontal and orthodontic scripts were found to be common for all the participants, which also agreed with the suggested framework for clinical reasoning in dentistry (Khatami et al., 2011).

Almost all of the participants were able to correctly diagnose the radio-opacity in the maxilla as a retained root, although the root was not well defined by lamina dura and the gingiva had healed over it. About half of the participants were able to correctly provide diagnoses using pattern recognition. They were mainly looking for a radio-opacity degree matching the tooth structure and the presence of lamina dura around the root giving it a defined outline. Only one of the Manchester interviewees used the forward reasoning, which is a characteristic of experts' reasoning when dealing with a difficult case. The most common process was the use of pattern recognition followed by the use of backward reasoning. A few participants also used a combination method to diagnose the remaining root.

For the third vignette, almost all Birmingham and Taibah interviewees were able to provide correct diagnoses for the white lesion as being lichen planus. However, only two Manchester participants diagnosed the lesion correctly. Nevertheless most of them were able to provide a list of possible differential diagnoses. Nearly half of the Manchester informants suggested taking a second opinion of a colleague or an expert. This finding could be a reflection of their PBL curriculum in which they are used to work as a group. With regard to the reasoning processes used to diagnose this lesion, half of the correct diagnoses were achieved by using pattern recognition. Backward and combination processes were also reported with only a few participants used the forward process. These finding may support the literature in that the forward approach is more common in experts rather than novices.

We may suggest that when students are confronted with a large variety of clinical cases they can develop scripts and use pattern recognition for diagnosis. This suggestion supported what Norman *et al* (2007) argued, that providing students with large numbers of similar clinical exemplars may facilitate the development of pattern recognition and hence the development of system 1 reasoning. One of the study findings indicated that the correct diagnoses for both lesions were commonly achieved by pattern recognition. We may suggest that the use of the pattern recognition strategy might be effective in learning accurate diagnoses in dental students. This finding supports the argument of Eva *et al* (1998) who stated that exposing students to a large number of clinical cases can help to enhance their problem solving ability.

As part of clinical reasoning we also discussed the management of the conditions (decision analysis). In case of managing the remaining root different options were available. The choice depends upon many factors including the assessment of the patient condition and her oral hygiene and functions, financial aspects, and patient's preference and expectations.

Students provided varied options when they discussed their management for the remaining root and provided reasons for their choice of management. Surprisingly, more than half of the participating Taibah students provided the option of extracting the remaining root, which was an acceptable option for the presented case, without discussing any reason behind their choice. Only one of them explained the reason that made him decide to extract the remaining root. This may again reflect the cultural and religious characteristics of the Saudi participant who kept the conversation short.

However, none of Taibah students mentioned the role of patients in decision making. This could be again due to the cultural view towards the dentists as being experts. This argument requires more investigation about the community and culture in SA. The other special characteristic of this particular group is that they were answering with the feeling of being assessed. They were focussing on providing the right answers without much elaboration. This could be due to the fact that they might be overwhelmed by the amount of summative assessment with very little or even no formative assessment, as discussed in Chapter 3. It could be also due to the fact of cultural impact on the gender difference and stereotype, in which males usually avoid long interaction with females and not feel comfortable when being *tested* by a female.

All the participants in Birmingham and most of the Manchester students provided reasons for their choice of management regarding the conditions of this special case. More than half of the participants from Manchester and Birmingham described the importance of the patient's involvement in deciding upon a management options.

Most participants from Birmingham mentioned that they need to investigate the possible causes of the white lesion and manage them accordingly. Some of the Birmingham and one of the Manchester participants acknowledged the pre-malignancy probability of the lesion and suggested that they should follow up the lesion regularly for possible changes. A few participants mentioned the need to inform the patient about the lesion and the possibility of malignant changes in the future. Those participants were from Birmingham.

Table 5:3: summary of the main differences between the three groups of participants regarding their interpretation of clinical reasoning and the reasoning strategies they used

	Birmingham	**Manchester**	**Taibah**
Familiarity with the term clinical reasoning	Mostly unfamiliar	Some were unfamiliar	All were unfamiliar
Level of reflection on own clinical experience when discussing examples of clinical reasoning	Low reflection	Some showed elements of reflection	No reflection
Interpretations of the meaning of clinical reasoning	Commonly referred to the necessity to decide on the best treatment option for the individual needs for the patient	Mainly referred to weighing up the advantages and disadvantages and risk and benefits of a specific treatment option that is supported by scientific trusted evidence.	Referred to effectively diagnose specific dental problems through their signs and symptoms, or other diagnostic aids such as radiographs and laboratory tests
Methods of learning clinical reasoning	Clinical sessions, personal effort, lectures and own experience	Own experience and IBL, EBL &PBL	Mainly personal effort , Text books and lectures
Reasoning processes: ritual reasoning	Common	Common	Some used ritual reasoning
Reasoning processes: periodontal scripts	Common	Some used periodontal scripts and most of them addressed the need for a second opinion	Mostly used periodontal scripts

Reasoning processes: orthodontic scripts	Common	Most of them used orthodontic scripts	Common
Reasoning processes: caries scripts	Common with a few participants required more investigation	Common	Common
Reasoning processes: diagnosing the remaining root	Mostly pattern recognition & 1 used deductive reasoning	Varied: 1 used inductive, 3 used deductive and 1 used a combination approach. The remaining used pattern recognition	Mostly pattern recognition & 1 used deductive reasoning
Reasoning processes: diagnosing lichen planus	Half of them used pattern recognition and a few used deductive reasoning	Mixed strategies (mostly inductive), but most of them were unable to make the correct diagnosis	Varied: mainly deductive reasoning and a few used pattern recognition and inductive reasoning
Diagnostic accuracy: the remaining root	All made the right diagnosis, but one changed her mind after making the right diagnosis. They also expressed their need for more investigation to formulate their final diagnoses	Almost all made the right diagnosis. They mostly expressed the need for more investigation. Half of them expressed the need for consultation and a second opinion	Almost all made the right diagnosis
Diagnostic accuracy: lichen planus	All made the right diagnosis	Two were able to correctly diagnose the lesion. All expressed their need for more investigation	Almost all made the correct diagnosis

Decision analysis	Commonly discussed the reasons behind their choices	Commonly discussed the reason of their choices	Half of them did not discuss the reasons behind their choices
The patient’s role in making clinical decisions	More than half mentioned the role of patient	More than half mentioned the role of the patient	None of them mentioned the role of patients in making clinical decisions

5.2.5 Limitations

In the current study a qualitative approach was implemented. Despite the claimed advantages of the interpretive approach (already discussed in the introduction section), qualitative methods are argued to produce highly situational-specific findings that are difficult to be generalised (Norman, 2003). Furthermore, participants who are asked to think-aloud may be focusing on the technique rather than the research question, especially if it involves other tasks such as language interpretation, as in case of Taibah participants (Boulouffe et al., 2013).

More research is required to study the role of clinical tutor and the system of clinical sessions at Taibah Dental School to explain our findings regarding the minimum role of tutors. Studying the relationship between students and tutors could also be helpful.

In order to compare the different effects of specific curriculum models on the development of clinical reasoning, all other factors affecting the development of this skill should be studied as well. In the case of the current study, cultural difference can play a prominent role. Most of the explanations provided for the Saudi participants' responses relayed mainly on the fact that the researcher was Saudi and had a deep understanding of what the culture looks like in this country. With the lack of literature to support our findings, we suggested that this might be the only choice to explain the possible effect of culture. More research is required to confirm our findings.

5.2.6 Conclusion

Our research showed that there was a lack of a proper understanding and appreciation of the importance of clinical reasoning in dental students. Therefore, we suggest that more support may be required and offered to the students in the form of taught courses as they evidently appreciate the importance of didactic teaching to foster the development of this skill. The type of assessment could also affect the performance of students when dealing with clinical cases. We argue that formative assessment could support reflection by students and this in turn could encourage a high level of reasoning skills development. PBL may foster a higher level of knowledge integration and reflection by the students than the two phase-curriculum model. However, the PBL curriculum model may not support the diagnostic accuracy of the students. It might also make them hesitant about being independent when making clinical decisions, as the need to have supporting opinions from other staff members was common among participants at the PBL curriculum. Pattern recognition is found to be an effective method of reasoning as most of the participants who used it mainly supplied correct diagnoses. This may support the effectiveness of exposing the students to a variety of clinical cases in helping them to develop scripts and consequently develop their reasoning ability. Forward reasoning strategy was uncommon among the participants. However, a few PBL students used it although not necessarily reaching a correct diagnosis. Finally, the patient role in decision making may need to be encouraged in dental students.

6 Chapter 6: Discussion and conclusions

Chapter outline

The current research aimed at understanding the relationship between the different educational strategies at the curriculum level and the characteristics of clinical reasoning in final year undergraduate dental students. In order to achieve this aim, two studies were discussed in the previous chapters. The first study involved comparing the clinical reasoning skills obtained from students' samples at three different dental schools, each implementing different curriculum models. The method involved a quantitative analysis of the results obtained by using a purposefully-created Clinical Reasoning Test (CRT). The second qualitative study complemented the first one and provided an approach to understanding the perceptions and subjective interpretations of clinical reasoning in students.

The current chapter will discuss the results of these studies in the wider context of the research aims, research questions and existing literature including theories and models of clinical reasoning. This will be followed by outlining the conclusion. Suggestions for curriculum development and future research will also be presented.

6.1 Summary of findings

In order to discuss the results of the current research, the main findings of each study are presented in Table 6:1 and **Error! Reference source not found.** below.

Table 6:1: Summary of findings: comparison between the clinical reasoning skills of final year students at three different dental curricula (Birmingham presenting an integrated curriculum, KAU presenting a traditional curriculum and Manchester presenting a PBL curriculum)

The type of undergraduate curriculum showed a minimal effect on the level of clinical reasoning in final year dental students as quantitatively measured by the CRT (Chapter 4)
• The CRT was both valid and reliable for testing clinical reasoning of our samples, Cronbach's alpha = 0.93 • Gender had a minimal effect on the students' performance in the CRT • Mean values of the total CRT marks indicated that students from King Abdulaziz (KAU) school, (at a traditional curriculum), performed slightly better than the other two schools. However, there was no statistically significant difference between the total CRT scores obtained by students from the three different schools. • Students at KAU performed significantly better than the students from the two other schools regarding two questions in the CRT. One of these questions was a KF item testing selection of information. The other was PMP item testing hypothesis generation • The participating experts performed significantly better than the students. They also spent less time to answering the test than the students • Some students avoided getting into discussing the psychosocial and ethical dilemma presented in one question in the CRT. Qualitative analysis for this question revealed that the majority of students chose to conform to the ethical principles of dental care regardless of what the patient had asked for • There was a weak positive correlation between the time spent by the students when taking the CRT and the final test mark obtained

Table 6:2: Summary of findings: clinical reasoning interpretations by final year dental students at three different curricula (Birmingham presenting an integrated curriculum, Manchester presenting a PBL curriculum and Taibah presenting an integrated curriculum); and the interpretive analysis of their reasoning processes and strategies

The qualitative analysis of the transcribed semi-structured interviews showed that characteristics of the clinical reasoning process and the students' interpretations of clinical reasoning were affected by the type of undergraduate curriculum (chapter 5)
• A high level of unfamiliarity and uncertainty of what clinical reasoning implies was common among the participants • Birmingham students commonly explained the necessity to decide on the best treatment option for the individual needs of the patient • The PBL students emphasized the importance of making clinical decisions based on weighing up the advantages and disadvantages and risk and benefits of a specific treatment option that is supported by trusted scientific evidence • Taibah students defined clinical reasoning as how to effectively diagnose specific dental problems through their signs and symptoms, or other diagnostic aids such as radiograph and laboratory test • Levels of reflection (by relating own clinical experience to the meaning of clinical reasoning) was lower among the participants on the non PBL curricula i.e. curricula with separate preclinical and clinical phases • Most of the interviewees stated that experience and their own effort and work are the most important methods for enhancing their clinical reasoning skills as well as acquiring sound knowledge base, mainly from taught courses • Ritual reasoning (discussing the clinical vignettes in professionally-known phases by dentists) was common among most of the participants except those from Taibah • Collaborative reasoning was a feature of the group of students undertaking the PBL curriculum • Clinical reasoning strategies varied depending on individual clinical cases. Pattern recognition was common when dealing with straight forward cases and inductive reasoning was uncommon among the participants • Pattern recognition usually led to the correct diagnoses • Diagnostic accuracy was lower for the PBL students when compared to that of participants on the integrated curricula • There was a lack of the patient consideration when making decisions especially among the Saudi participants • Assessment methods and culture appeared to have an impact on the students' clinical reasoning • Taibah participants spent less time when discussing the clinical vignettes compared to the other two groups

- Pattern recognition triggered by visual cues was also common among all participants for detecting common dental disorders e.g. caries scripts

6.2 Discussion

The aim of this project was to understand the impact of the different types of dental curricula on the characteristics (including understandings, methods and strategies) of clinical reasoning at the undergraduate level. In order to achieve this aim mixed methodologies were used and different methods for data collection and analysis were employed.

An analysis of the models of the four different curricula involved in the research, informed by the principles of the SPICES and the Integration Ladder frameworks, was conducted. Two main empirical studies were also carried out. The first was presented in Chapter 4. It involved a quantitative comparison of clinical reasoning skills using a specially designed online test (CRT). The second study implemented a qualitative interpretive approach. It involved a thematic analysis of transcribed semi-structured individual interviews. This study was presented in Chapter 5.

The collective results of these studies should be understood as complementary in providing answers to the original research questions posed in Chapter 1 as presented in Table 6:3, below. A discussion of the results guided by the research questions will be provided in this section. The combined perspectives of these studies *i.e.* looking into the characteristics and the process of clinical reasoning; and simultaneously comparing the results may give a distinctive value to the current project hoping to contribute to the body of knowledge of clinical reasoning and its relationship to the curriculum. To the author’s knowledge no research has been conducted to understand what dental students think of clinical reasoning and how it can be learnt from their perspectives.

Table 6:3: A list of the research questions and their answers referring to the specific section in the present thesis which discussed them

Research questions	Related sections
• How have the effects of curriculum on clinical reasoning been reported in the literature? • What are the similarities and differences between the four types of curriculum (involved in the current research) in their models, aims, strategies, assessment, clinical exposure, and clinical reasoning opportunities?	Chapter 3 provided a review of the literature discussing the suggested impact of the different curriculum models on clinical reasoning, diagnostic ability and other related skills. It also mentioned the regulatory bodies in each country and their objectives. Analysis of the four dental schools curricula was provided and compared based on the components of the SPICES model, level of integration based on the Integration Ladder model, objectives, assessment, clinical exposure, and clinical reasoning opportunities.
• How can clinical reasoning be assessed? • How can we create a valid and reliable test combining the elements of established clinical reasoning tests? • What are the differences between the results of different cohorts of students, and how can they be related to their curriculum types?	A literature review of the methods and tools used to assess clinical reasoning was discussed in Chapter 2. Chapter 4 provided the method used to create and validate a clinical reasoning test (CRT). The results of our comparison of the marks obtained from the different groups of students were discussed and related to their types of curricula.
• What does clinical reasoning mean to students? • What do they think of clinical reasoning development and the effective teaching strategies? • How do their reasoning processes and strategies differ?	An interpretive study was described in Chapter 5 that explored students' view about clinical reasoning and the effective methods for its development. This qualitative analysis also revealed some differences between the

• Are there any curriculum factors affecting their reasoning characteristics?	different groups of students based on the characteristics of their curricula. More factors were discussed which were thought to have an impact on the students' clinical reasoning.

6.2.1 The CRT

The developed CRT was especially designed for the purpose of this research. Most of the different components of the clinical reasoning phenomenon, based on the literature, were tested. This test consisted of a mixture of different clinical assessment tools in order to combine their advantages. Our CRT was both valid and reliable for the current research purpose. Construct, content and face validity measures were carried out and the reliability value, as indicated by Cronbach's alpha, was 0.93. The application of this test to measure clinical reasoning in final year dental students from three different curricula provided an overview of the curriculum effect on clinical reasoning.

The fact that we did not find differences related to gender or curricula may indicate that the CRT is an assessment tool that can be widely used to assess clinical reasoning. The results in this case would not be affected by factors such as curriculum or gender.

6.2.2 The effect of gender on clinical reasoning

The relationship between student's gender and their performance in the CRT was studied in the current research. The male participants performed significantly better than the females regarding only one question in the CRT (a KF question testing the selection of information). This difference might result from the difference in the sample size (31 males and 98 females) and the of effect large number, to be explained later. On the contrary, the mean value of the total test mark was slightly higher for the female sample, being 26.04 compared to 25.67 for the male sample. The statistical analysis indicated that there was no effect of gender on the students' performance in the CRT as indicated by their total test marks. This finding supports the claim made by Da Silva, (2013) who found that there is no association between gender and students' performance in a clinical reasoning test taken by medical students.

However, our finding of the absence of the gender effect on students' clinical reasoning contradicts that of Groves *et al* (2003a), who identified female gender as a positive predictor for clinical reasoning ability. This may be explained by the fact that the Groves *et al* study used two different types of clinical reasoning assessment and that their results suggested gender effect in only one of these tests (namely Clinical Reasoning Problems). Their sample was also different from what we have included in this research. They studied clinical reasoning in PBL students at a single medical school, whereas students from three dental schools with varied curricula have participated in our quantitative study.

6.2.3 The effect of the curriculum on clinical reasoning

The current research found that the impact of the curriculum on the assessment of clinical reasoning is minimal for final year dental students. Similar finding was argued by Da Silva (2013), who conducted comparative research in medical students. Her sample included medical students from three different curricula (PBL, integrated and traditional) at different stages of the undergraduate education. Although she found some differences in the levels of clinical reasoning related to the types of curriculum, these differences were not significant in the final year student sample. A suggestion can be made that the curriculum effect on levels of clinical reasoning decreases when students approach graduation.

To explore more details of our findings, we measured the levels of different elements of clinical reasoning. As mentioned earlier, our instrument (CRT) was developed to evaluate different components of clinical reasoning. The results showed that students from the traditional curriculum performed significantly better than the other two cohorts regarding answers to two questions in the CRT. These questions tested the selection of information and hypothesis generation. Some suggestions may be used to explain these findings. By looking into the traditional curriculum of King Abdulaziz Dental School (KAU) we explained that it takes the students six years to complete their BDS program unlike the comparatively shorter courses provided by the other schools. In KAU clinical training takes place in the third year and continues until the final year. We suggest that this comparatively long time during the undergraduate course can help students to develop the experience required for clinical reasoning. We argue that stage theory (discussed in Chapter 2), which is suggested to explain the development of expertise in medicine, (Boshuizen and Schmidt 2008) can also be applied in dentistry. In this case students take time to develop their clinical reasoning expertise.

We also suggest that the requirement-based system for clinical assessment used in KAU may expose the students to a large variety of dental problems. This in turn can aid the development of their problem solving skills (Eva et al., 1998). Confronting students with a large number of variable clinical cases can also help them to develop scripts and enhance their reasoning ability (Norman et al., 2007). However, there have been many advantages of competency-based education over the traditional requirement-based approach, such as improving the interdisciplinary understanding by students and overcoming the redundancy associated with traditional curricula. This may consequently reduce the load on students and give them more time to reflect on their learning (Yip et al., 2001). Another explanation we can think of is that the redundancy of information in the traditional curriculum may also consolidate basic science knowledge which may also be used to solve dental problems. The importance of knowledge in clinical reasoning is well known (Kaufman et al., 2008).

It would have been useful if we could have included this cohort of students *i.e.* KAU students in our qualitative study to further explore this. Unfortunately, this would have required a long process of getting approval from the researcher’s sponsor and the dental school and would have required a budget for more data collection.

Another explanation could be related to the characteristics of the students’ samples who have taken the CRT. The traditional curriculum cohort constituted the largest sample (the total number of KAU participants was 53). The comparison between the three cohorts could be affected by the sample size in which the integrated and the PBL samples (being 39 and 37 participants, respectively) were underrepresented. This limitation of our study can be explained by the law of large number which implies that in smaller samples there is a higher likelihood of having cases that do not conform with the norms (being either much better or much worse) (Durrett, 2010). At the end the difference was only related to two questions in the test and although the mean values for the total CRT marks was a little higher in case of KAU (27.44 compared to 25.23 & 24.58 for the other schools), there was no overall statistically significant difference in favour for the KAU students regarding their overall performance in the CRT as indicated by the total test marks.

When looking into the effectiveness of the PBL curriculum in fostering the development of clinical reasoning skills, we found that the mean value of the total CRT marks obtained by the participants in this type of curriculum was slightly lower (24.58) than that obtained by participants in the other two cohorts (traditional: 27.44; integrated: 25.23). However, as mentioned above there was no statistically significant difference between the total test marks obtained by students from the three schools.

Complementary results were obtained from our qualitative study. In this study the PBL sample also attained the lowest diagnostic accuracy, especially for the vignette discussing the white lesion in the buccal mucosa (only two of the eight PBL participants made the right diagnosis). Diagnosing this lesion is not straight-forward as it can be easily mixed up with other white anomalies affecting the oral tissues (Parashar, 2011). This finding supports what Kaufman *et al* argued about diagnostic inaccuracy being common among PBL students. They suggested reasons for this issue. They argued that teaching biomedical science knowledge in association with clinical knowledge may facilitate their integration. However, this strong association between these two types of knowledge may render the PBL students unable to effectively separate them when there is a need for application of the biomedical science knowledge to another clinical context in another clinical case (Kaufman et al., 2008).

Our finding of the low diagnostic accuracy of the PBL students compared to the traditional and integrated students also supports the findings of Goss *et al* (2011) who found that the PBL medical students had a lower level of diagnostic reasoning than students at a traditional curriculum. However, the characteristics of their sample could have affected their results. The PBL sample they studied were trained in a system based PBL format with little clinical training compared to their comparative traditional curriculum sample who was receiving extensive clinical practice. Now we can put forward the argument that the *educational strategies* rather than the curriculum models should be the main factors influencing clinical reasoning skills. We will discuss this argument later.

The previous finding also agrees with some studies in the literature which indicated the marginal effect of the PBL curriculum over the traditional curriculum in enhancing students' diagnostic ability (Jolly, 2006, Colliver, 2000, Pardamean, 2012b). This finding, however, disagrees with other studies which challenged this argument (Albanese, 2000, Norman and Schmidt, 2000, Schmidt et al., 1996). In particular, Schmidt *et al* (1996) have studied the effectiveness of the different medical curriculum models. In their study they compared clinical reasoning of students from traditional, integrated and PBL curricula. They argued that the diagnostic accuracy was higher for the PBL and integrated curricula than that for students in a traditional curriculum. However, our results disagree with what Schmidt *et al* argued in their comparative cross-curricula study. Some similarities were found between our quantitative study and their study. These included comparing similar types of undergraduate curricula by using a case-based assessment tool for clinical reasoning. Both studies were cross sectional and limited the students' freedom of accessing some information to avoid the possibility of consequential error. Multiple cases were used in both studies. However, we have used only five clinical cases compared to their short 30 cases summarising the signs and symptoms of clinical vignettes. In this case we can think of our results as a product of case specificity which might provide little information for curricula comparison. The material used for that study was different from our CRT in which we have used a mixture of different clinical reasoning tests in which we included management decisions in addition to what they assessed as diagnostic decisions. We also aimed at assessing more elements (rather than the single assessment of diagnostic accuracy) of the clinical reasoning process, *e.g.* selection of information.

Comparing our findings to Da Silva's (2013) results would be suitable to support our proposed argument about educational strategies rather than the model of undergraduate curriculum being more important in fostering the development of students' clinical reasoning. She compared clinical reasoning of students in a traditional, an integrated and a PBL medical curriculum. Her study involved using a clinical reasoning test which was similar to our CRT in that it involved a mixture of clinical reasoning assessment tools. However, this test differed from ours in that it involved discussing only two long clinical cases. Her study involved targeting medical students at different stages in their undergraduate courses. She suggested that the PBL students performed better than the other two groups regarding the results of one of the cases. She also found that students in the integrated curriculum performed better than those from the traditional and the PBL curricula regarding the results of the other case in the test. However, she found that there was no significant difference between the marks obtained by students in their final year from the three different curricula. The results of our quantitative study support this finding as our sample only involved students in their final year.

In summary, there has been always debate on the effectiveness of PBL in the medical and dental educational literature. One of the suggestions as to the causes of these conflicting results could be related to the variations of the PBL format used. Hence, this also supports our previous argument of that the educational strategies rather than the type of curriculum should receive more attention. Longitudinal comparative cross-curricular studies with repeated and variable measures for clinical reasoning assessment over a long period of time may be required to reach a conclusion about the superiority of a specific model. Including a comparison of the hidden curricula would also be helpful. However, reaching such a conclusion might be impossible due to the fact that clinical reasoning is affected by many variables which could be difficult to control.

6.2.4 The effect of knowledge on clinical reasoning

In the CRT other elements of clinical reasoning were tested including the acquisition of knowledge. There is a consensus in the literature that knowledge forms the fundamental basis of clinical reasoning (Eva, 2005, Norman, 2005, Rikers et al., 2004, Boshuizen and Schmidt, 1990, Schmidt et al., 1990). Testing of knowledge should be a part of any reasoning test, as explained by Van der Vleuten and Newble (1995). Analysis of the quantitative data showed a strong positive correlation between the participants' performance in the CRT and the marks obtained from knowledge testing questions. Although we have tested student's knowledge by using only two questions, statistical analysis showed that the results of these two items were positively correlated with the final test mark. This finding supports the literature about the importance of knowledge in clinical reasoning.

The traditional and the integrated curricula specify the first years of their courses to teach biomedical science knowledge (Norman and Schmidt, 2000). In the PBL curriculum this knowledge is taught in an integrated way with the clinical knowledge (Kaufman et al., 2008). We suggest that a PBL student may still be exposed to new knowledge of diseases until they reach their final year, during which he/she is expected to cover a wide range of factual knowledge. This suggestion might have also affected the overall test marks obtained by the PBL sample and the comparatively lower level of diagnostic accuracy.

6.2.5 The effect of experience on clinical reasoning

Experience is another well-known factor which is positively associated with clinical reasoning (Patel et al., 1996, Smith et al., 2010). The results of the CRT supports this argument in that mean values of the total test marks for our experts' sample was significantly higher than that of the total students' sample being 35.71 and 25.95, respectively. Experts also spent less time taking the test compared to the students' samples. This finding supports the argument in the literature that experts spend less time reasoning than the less experienced individuals (Hong Kong Polythechnic University, 2014, Smith et al., 2010).

6.2.6 The effect of the time spent during taking the CRT on the results

Another notable finding was that there was a weak positive correlation between the total test mark and the length of time spent by the participants while taking the test. As the CRT was an online test, there was a concern that the participants might search the internet or look for answers from other resources. However, this weak correlation can be explained by the fact that the presented clinical scenarios were specifically created for the CRT and were not copied from resources and some of them presented real clinical cases. Participants who spent comparatively longer time taking the test may benefit from reviewing their information, especially regarding the knowledge based questions, which could have helped them to improve their answers. However, because these questions constituted only a small portion of the CRT (two questions out of 31), the positive effect of the time spent was minimal, and the CRT was mainly assessing their clinical reasoning skills rather than searchable pieces of information.

6.2.7 The psychosocial aspect of the CRT

The CRT was also designed to test the psychosocial aspect of dental care. This element was tested in different questions. One of them required an open ended answer. The qualitative analysis of the answers to this question (question 22) revealed that there was a high percentage of students who did not answer it. This could be related to the fact that the students' contribution in the study was voluntary and they felt that it is unnecessary to get involved into sophisticated and sensitive decisions. However, analysis of the obtained answers showed a general agreement on the importance of conforming to ethical guidelines of dental care despite the need to perform certain dental procedures in order to complete the clinical requirements or the patient's choice. This finding supports Broers *et al* who found that dentists' decisions are greatly affected by ethical and legal guidelines (Broers et al., 2010). It also supports Khatami's (2011) results of the common ethical reasoning (explained in Chapter 2 on page 47) among dental students.

6.2.8 Students' understanding of clinical reasoning

The results of the thematic analysis (in the qualitative study) showed that most of the participants, especially from Taibah and Birmingham Schools, were unfamiliar with the term 'clinical reasoning'. A few Manchester participants (representing our PBL sample) seemed to be somewhat familiar with what clinical reasoning implies without being probed by the interviewer. However, some of them were still uncertain about the accuracy of their answers. To explain their responses we may suggest that the PBL sample may be more inclined to search through different resources in order to discuss clinical cases for their PBL sessions. Many of the scientific articles and text books refer to how to differentiate between similar conditions and how to make proper diagnostic and management decisions. Some may also include terms like decision making or clinical reasoning. There might be other factors also affecting their responses, such as that the term being mentioned by tutors. However, we suggest that dental students need more emphasis on what clinical reasoning means. Formal teaching of clinical reasoning is suggested in the literature to help the development of this important skill in students (Tokede et al., 2013) and explaining the term clinical reasoning could be the first step in teaching it.

Our student samples interpreted clinical reasoning in different ways which might reflect a possible effect of different curricula. Most of the participants from Taibah mentioned the importance of effectively relating the signs and symptoms of the condition to the diagnoses and decisions to be made. In order to explain their responses we found that although the curriculum at Taibah showed an intermediate level of integration, it was still preserving most of the characteristics of the traditional curriculum. The level of curriculum integration was comparatively lower than that of the other two schools. Pardamean (2012b) found that students at a traditional curriculum usually tend to use hypotheses driven approaches to diagnose dental problems. They are inclined to suggest hypotheses and associate them with different signs and symptoms when they deal with clinical cases. This finding may explain the interpretation of the meaning of clinical reasoning by Taibah participants.

On the other hand, Manchester participants described clinical reasoning as making clinical decisions based on weighing up the advantages and disadvantages and the risks and benefits of a specific treatment option that is supported by scientific trusted evidence. Their point of view could also be related to the PBL format in which students are required to support their suggestions for possible diagnoses or management decisions by scientific evidence that is commonly required when discussing clinical cases with peers during the PBL sessions. Furthermore, the use of Evidence based learning is a feature of their school curriculum, see Chapter 3.

Participants at Birmingham addressed the need to provide the best treatment options which are tailored to the individual patients' needs. This could reflect some teaching strategies used at this particular school. The Dental School at the University of Birmingham uses different teaching resources including electronic courses which supply discussions of a large number of varied dental vignettes.

Despite our previously discussed results regarding the questionable effectiveness of the PBL curriculum in enhancing the students' clinical reasoning, the PBL participants showed a high level of reflection and integration between biomedical science knowledge and clinical practice. This was reflected in their frequent association and reference to what they have experienced in clinic when they have discussed the meaning of clinical reasoning in our qualitative study. This integration of clinical problems and biomedical science knowledge among the PBL students was supported in the medical literature (Norman and Schmidt, 1992). In contrast to the PBL sample, the other two samples (presented the integrated curriculum type) showed lower levels of relating what is taught and experienced in clinical work to what clinical reasoning means to them. This finding was more prominent in case of Taibah sample than the Birmingham sample.

Most of the participants saw the development of clinical reasoning as an ongoing process mainly dependent on their own work and experience. They also appreciated the importance of knowledge from scientific resources and the experience of other staff members as methods of learning clinical reasoning. Lectures were also found to be effective in learning clinical reasoning as perceived by students, even for the PBL respondents, where little focus is usually given to lectures. Although we cannot relate our findings to the literature, due to the lack of research on how students interpret clinical reasoning, we argue that lecturing could be effective in teaching clinical reasoning as it was valued by the student samples. The other important point would be that because students see that clinical reasoning developing by them building on their own experience, educational strategies could be directed towards providing enough clinical experiences for the students to help them relate and integrate their knowledge in order to develop their reasoning skills. Most of the recommendations in the literature suggested that confronting students with a large number of clinical cases and clinical experiences can aid the development of their problem solving skills (Eva et al., 1998, Norman et al., 2007, Ericsson, 2004, Smith et al., 2010).

6.2.9 The effect of the curriculum on the clinical reasoning process

When we analysed the clinical reasoning processes used by the student sample we found that they used different strategies and processes depending on the presented clinical vignette. This is further supported in the dental literature. Khatami *et al* (2011 & 2010), who suggested a framework for clinical reasoning in dentistry, argued that an individual student uses different reasoning strategies when dealing with different vignettes. Another finding of the current research also supports this framework as certain scripts were common among dental students *e.g.* caries scripts.

Khatami's (2010) framework suggested that ritual reasoning is common in dental students. However, our results only partially support this finding. This type of reasoning was common among Manchester and Birmingham participants but not among Taibah participants. Here we can explain this by the fact that there might be other factors affecting the behaviour of Taibah students, specifically cultural factors. Although Khatami argued the popularity of ritual reasoning in dental students, she also mentioned that some students in her study were not convinced by the necessity of going through the stages of ritual reasoning while still conforming to them. For that reason we can explain our findings regarding Taibah informants as they tended to shorten the conversation because of a female interviewer (for cultural and religious purposes) by excluding these marginally important steps (in their perspectives) of ritual reasoning. More research may be required to support this suggestion. This can be supported by carrying out interviews using the same protocol with the same sample conducted by a male interviewer.

The reasoning processes used by our student samples were varied, but the special thing about them is the fact that inductive reasoning was uncommon among our samples.

However, a few Manchester students used this type of reasoning, although not necessarily led to correct diagnoses. The results of Pardamean's study (2012b) suggested that the PBL curriculum might improve inductive reasoning in dental students. However, his suggestion was based on statistically non-significant difference between the scores obtained by students in a traditional and a PBL curriculum when they answered a survey designed to test critical reasoning with subscales including inductive reasoning. However, there is a lack in the dental literature for cross-curricula comparative studies implementing interpretive approaches to further support that the PBL students use inductive reasoning more than students from other curricula. We also think that because most of the students in this sample did not correctly diagnose the white lesion, they were trying to elaborate on the provided information hoping to reach the diagnosis.

In other words, it could be possible that when the student fails to diagnose a condition by pattern recognition or backward reasoning he/she uses forward reasoning. This suggestion was put forward because our results showed that the PBL students used inductive (forward) reasoning mostly when they discussed the third vignette to which most of them did not provide the correct diagnosis.

Another finding of the qualitative study was that participants who used pattern recognition usually made the correct diagnoses for the clinical conditions presented. This finding may support what is argued in the literature about experts being more reliant on pattern recognition and have more diagnostic accuracy compared to novices (Neufeld et al., 1981, Hendricson et al., 2006, Bransford, 2000). This finding may indicate the importance of patterns development in making diagnoses. It also supports what is known about the development of expertise and the associated development of scripts and patterns, (discussed in Chapter 2 on page 60). We also support the recommendations put forward by educators about the efficiency of exposing students to a large variety of clinical problems to aid the development of scripts and consequently develop their clinical reasoning (Eva et al., 1998, Norman et al., 2007) via the reliance on system 1, see Chapter 2.

Furthermore, Norman and Eva argued that diagnostic errors mostly happen when a clinician use the systematic approach to reasoning. They also challenged what was thought about that intuitive reasoning (system 1) being the cause of diagnostic errors.

One special feature of our PBL sample is that they frequently addressed the need for a second opinion and they requested more information compared to the other two cohorts. This can be explained by the PBL format of learning in groups in which students usually share their views and cooperate to solve clinical cases. Again, the dental literature is deficient in similar research to support this argument. This result and the fact that Birmingham participants also mentioned the need to take a second opinion in case of uncertainty supports what is argued about the importance of social factors in the context (clinical environment) (Croskerry, 2009, Higgs and Jones, 2008a). However, none of Taibah participants mentioned the need to get a second opinion. Their response could be related the gender stereotype (men are usually seen as independent, and asking for help can be perceived as a sign of weakness).

One of the important findings of the current research is that the role of the patient in making clinical decisions was barely mentioned by the UK participants and was not mentioned at all by the Saudi sample, which might suggest that the role of patients in contributing to clinical decisions may need to be emphasised in dental students. This finding supports what Chapple *et al* (2003) argued about the role of patients in making clinical decisions being limited in dentistry. Their study involved a questionnaire survey of the clients in dental practice about their views of their role in making decisions. Those patients reported that they would like to participate in making decisions, but they actually felt themselves as being passive in this process. They also ascribed this to their low levels of dental knowledge and the trust in their dentists. Culture and the specific system of dental care in Saudi Arabia might contribute to this behaviour by Taibah informants. Dental care is provided for free in Saudi Arabia and most of the Saudi dentists usually work for the government sector. The dental care receivers may feel themselves being fortunate to be treated in the public centres and tend not to discuss the available options with their trusted dentists. Research is required to support this argument.

Another finding was that the assessment strategies and culture can have an effect on the students' clinical reasoning. Taibah participants commonly avoided long conversations. The average length of time was calculated from the recordings. It was found that this time was 10:02 minutes for Birmingham participants, 11:15 for Manchester participants and 8:29 for Taibah group. Taibah participants also appeared to feel like their performance was being tested by the interviewer. There is a lack of formative assessment in the Taibah curriculum. For that reason we suggest that those students usually focus on providing the right answers rather than the process of answering. We make this suggestion based on the participants' actions after completing the interviews, as almost all of them checked their answers with the interviewer. Avoiding long conversations and providing answers without much elaboration could also be a result of the cultural characteristics of those participants. Males usually avoid long discussions with females for religious purposes and special gender stereotype also dominated the Saudi culture. However, there is a lack of cultural research in this country and most of the arguments made are based on the author's experience of being a Saudi dentist. A further supporting evidence is that the issues associated with gender stereotype (the male's superiority) are commonly discussed in the media as being an unfair issue rooted in the Saudi culture and considered against the Islamic religion (Althaminah, 2015).

The average time spent by Manchester participants also supports our previous argument of that those students tend to ask more questions and requested more information during the interviews. This time might also be spent by the participants when they were trying to diagnose the white lesion in the buccal mucosa as most of them failed to provide the correct diagnosis.

6.3 Conclusions

In conclusion, teaching strategies were found to be more important than the type of curriculum in fostering the development of clinical reasoning skills in dental students. Cultural factors and the assessment strategies were also found to affect students' clinical reasoning. Pattern recognition (intuitive/system 1) reasoning is found to be the most effective strategy used by the students to reach a correct diagnosis. Therefore, we suggest that educators focus on developing this strategy to clinical reasoning by confronting students with a large variety of clinical cases. This in turn may help students to develop scripts and patterns. We also suggest that dental students need to be aware of clinical reasoning, its implication and how to develop it. Patients' role in clinical decision making may need to be reinforced in dental students.

6.4 Implications for curriculum development

In this section implications for curriculum development to facilitate the development of clinical reasoning skills will be presented in light of the current research findings and the previously identified recommendations in the literature.

Our analysis of the undergraduate curricula of the four dental schools showed that with the exception of the PBL school all the other schools mainly depend on the clinical phase of the course in developing clinical reasoning skills. The PBL school, however, claimed that students encounter clinical cases from day one at the school. Analysis of the traditional and the integrated curricula involved in the study found that there are no explicit learning opportunities for the students to develop their reasoning skills in the preclinical phase.

All the analysed curricula mentioned clinical reasoning or similar terms as an objective to be achieved by the clinical training, especially in the final years. Most of these did not explicitly mentioning clinical reasoning opportunities or efforts to develop this crucial skill by strategies other than clinical training. However, our analysis was mainly based on the publicly-available information. Other sources of information could possibly highlight alternative opportunities for students to develop their clinical reasoning. However, we still believe that publicly-available sources of information should mention any planned opportunities for developing clinical reasoning, as students depend on them to get information about the course.

Our findings indicated that most of the final year students were unfamiliar and uncertain about what clinical reasoning means. This further supports the need to mention clinical reasoning and its importance in the course description. Students should understand this process and be directed towards developing it early in the course. Kassirer stated that teaching clinical reasoning should not be delayed until students gain a full understanding of anatomy and pathophysiology (Kassirer, 2010, Kassirer et al., 2009). Putting more effort to this may help the students to reflect on their learning process and think of their clinical reasoning skills development. They might be more aware of the opportunities for them to develop their skills. This suggestion is also based on the fact that knowledge, cognition and meta cognition were all main components of the clinical reasoning phenomenon (Higgs and Jones, 2008a).

The research findings indicated that students value the importance of lectures in learning clinical reasoning. Consequently we suggest that including lectures about clinical reasoning, its different processes and the important strategies to develop it might be an effective method of teaching clinical reasoning. Lectures could also include presenting clinical cases to students and talk through them, making connections on how to differentiate them from similar cases and how to make management decisions that are supported by scientific evidence. Since the students in our sample think of clinical reasoning as being an incremental process that develops through personal experience, every effort should be directed towards helping the students to develop their reasoning skills. Formative and summative assessments are both important and should reflect the importance of clinical reasoning. Providing feedbacks can be helpful in enhancing the students' reflection about their clinical reasoning skills. More suggestions for teaching strategies were already discussed in the previous section and in Chapter 2.

6.5 Implications for future research

6.5.1 Consensual framework

After conducting a literature review we found that research on clinical reasoning is lacking in dental education. Most of the reviewed literature came from medicine and other health care disciplines. Although dentistry shares many features with general medicine, there are still many characteristics which are unique to the dental practice. These include factors affecting the clinical reasoning process *per se* and its special characteristics together with the fact that dentists usually diagnose, decide on management options and actually perform treatment procedures commonly in one visit. Providing a framework for clinical reasoning in dentistry was not available until 2010 (Khatami, 2010). More research is still needed to get a deeper understanding of this process and to confirm the applicability of this framework to the varied dental specialities.

Dentistry is a field with different specialities including oral surgery, endodontics, operative dentistry, paedodontics and orthodontics. Every speciality has its own characteristics. An oral surgeon for example may see the patient for one or two visits during which the focus would be given to the technical aspect of the dental treatment. On the other hand, an orthodontist may see the patient more frequently over a long period of time which might extend to several months or years. Here it is not uncommon for the dentists to develop relationships with their patients, which definitely affects the decision making process. An example of this could be changing the treatment planning according to the patient's motivation towards the treatment, sometimes the orthodontist may choose to exchange the fixed braces for removable ones if the patient is not maintaining a good oral hygiene in order to protect his sound teeth. Another example could be the choice of a management procedure or restorative materials which might be more suitable to the financial status of the patient. Another dental speciality may include dealing with patients with special needs. In this case the dentist may focus on the psychosocial aspects beside the technical ones. Working in emergency clinics can also affect the decisions made by the dentists and so on. For that reason we feel that research is needed to supply frameworks for clinical reasoning in each dental speciality.

In order for dental education to be more effective in fostering the development of this important skill of clinical reasoning a consensual definition as well as a framework should be first agreed upon. Educators should be able to understand what clinical reasoning means in order to facilitate its development in their students and provide effective measures to assess its level. Then more research is also needed to study the effectiveness of educational strategies to develop the students reasoning skills.

6.5.2 Factors affecting the development of clinical reasoning

Research is also lacking in case of understanding the dynamics of clinical reasoning as a process and its different affecting factors in dentistry. We already discussed some factors in Chapter 2 which might have an impact on clinical reasoning and problem solving. The current research identified the possible effect of culture and educational strategies in dentistry. Further studies are required to support and expand these findings. Understanding these factors may help the educators to manipulate them in a way that help students to develop their clinical reasoning skills.

6.5.3 The development of clinical reasoning

Research is needed to understand how clinical reasoning develops in dental students and what stages are involved in its development. Studying the progress of clinical reasoning skills development may be helped by targeting dental students in longitudinal studies through all the stages of their undergraduate course. Here we can get an understanding of the development process and educational strategies might be tested for their effectiveness at different stages.

Longitudinal studies are also effective in providing more information about the impact of the different curriculum models on the development of clinical reasoning. Using the special test (CRT) developed for the purpose of this research could be also helpful to assess the different components of clinical reasoning. A major limitation of the current research was the reliance on cross sectional studies rather than longitudinal ones and not including the components of informal and hidden curricula. Although longitudinal studies take time and require multiple episodes of data collection, it might be the perfect way to track the development of clinical reasoning and carry out more precise comparisons between students at different curricula, especially if the schools to be compared were non-homogeneous (Muijtjens et al., 2008). However, we still believe that comparing different student samples at different curricula could not be precise unless all the variables are controlled (including elements of informal and hidden curricula) which would be difficult and perhaps even impossible. This, in part, could be due to the fact that more elements of the hidden curriculum are still not yet discovered and analysing them is usually not straight forward (Mossop et al., 2013). Furthermore, Norman (2003) concluded that even if a study proved that a specific curriculum was superior to another, there still would be other factors playing roles, and researchers will be constantly wondering about the nature and the effects of these factors.

6.6 Limitations

The limitations of the current research were already mentioned in Chapters 4 and 5, but we will summarise them here. We think that the sample size could have affected the quantitative analysis of the CRT results obtained by the different groups of students. Different sample sizes were analysed which might underrepresent some groups making the comparison unfair. The low sample size involved in the study may indicate the un-generalisability of the results.

Comparing clinical reasoning in students from different curricula might be better researched by studies targeting the students at different levels of their undergraduate study. Time constraints resulted in the difficulty of conducting longitudinal research. This kind of research may provide better understanding of the development of clinical reasoning in students.

The CRT involved discussing only five dental cases. This might have the limitation of content specificity when compared to other clinical reasoning assessment tools in which a large number of clinical cases are included.

The use of qualitative methods can produce highly situational-specific findings that are difficult to be generalised (Norman, 2003).

6.7 Reflexive account

I graduated with a BDS qualification at a Dental School in Saudi Arabia. The curriculum was purely traditional at that school with its 'spoon-fed' teaching in the preclinical phase and the long list of clinical procedures requirements in the clinical phase. Having all this amount of information in a foreign language (English instead of Arabic) added to the stress I (and most of my colleagues who were incompetent in English) was facing. After graduation, I worked as a general dentist for a couple of years at a public dental centre. I then got a job as a teaching staff at a newly established dental school (Taibah). The school Dean was enthusiastic about developing the school in a conventional way to provide a special BDS course in which advanced teaching strategies are used. He recommended that I get qualifications in dental education to help the development of the school curriculum.

Here my research journey began and I was funded to do Masters and PhD qualifications in medical education. The first thing that came to my mind was studying the stress among dental students for my Master's dissertation. I found that dental students at the university which I got my BDS degree from were suffering, like other dental students worldwide, from high levels of stress mainly related to academic factors.

When I started my PhD study, I was interested to look into one of the most important skills required by dentists. I was reviewing the time during which I was working as a dentist. During that time as a newly graduated dentist I was struggling to trust my decisions without supervising experts being there to check them for me. I learnt a lot during my clinical practice and I started developing my individual scripts and experience. My PhD supervisor was supporting me during my research of clinical reasoning by providing advice and suggestions for developing my research. I started by searching the literature in clinical reasoning and found that there is still much to be found about this mysterious process. There is still no consensual definition or interpretations for it. Reviewing the assessment tools revealed that there is no consensual way to assess it as well. This drove my curiosity to develop a new assessment tool by combining some of the already known tools for clinical reasoning assessment. After applying this test to the different cohorts of students at different curricula, I found that there was not much difference between them to support my initial hypothesis about the curriculum effect on clinical reasoning levels. I thought it might be helpful to get a deeper understanding of the curriculum effect by implementing an interpretive approach. The idea of getting a view about what clinical reasoning means to the students was also raised and I found it really helpful to get that as well especially that this was not being previously researched. Responses of the interviewers and their unfamiliarity with clinical reasoning made me feel responsible to describe it to them and raise their awareness of how to develop it after the interviews were completed.

The results of this study helped me in the first place to understand clinical reasoning as a phenomenon and would hopefully contribute to the body of knowledge regarding clinical reasoning in dentistry. I would be still interested in carrying out more research into the factors affecting clinical reasoning other than the curriculum. The sequential development of clinical reasoning in dental students would also be a possibility for future research when I go back to my country as it would be easier to conduct a longitudinal study in a school which I work at with no time constraints. At the end what I have achieved would be motivating me to do more research and develop the dental curriculum to produce better independent dentists who can provide better dental care to the community.

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8 Appendices

Appendix 1: Ethical approval

Direct line/e-mail
+44 (0) 115 8231063
Louise.Sabir@nottingham.ac.uk

The University of Nottingham

Faculty of Medicine and Health Sciences

Medical School Research Ethics Committee
Division of Therapeutics & Molecular Medicine
D Floor, South Block
Queen's Medical Centre
Nottingham
NG7 2UH

Tel: +44 (0) 115 8231063
Fax: +44 (0) 115 8231059

20th December 2011

Professor Reg Dennick
Associate Professor
Faculty of Medicine and Health Scienes
B Floor, The Medical School
QMC Campus
Nottingham University Hospitals
Nottingham
NG7 2UH

Dear Professor Dennick

Ethics Reference No: U/09/2010 - ***Please quote this number on all correspondence***
Study Title: Clinical Reasoning Development in Medical Students: an Educational and Transcultural Comparative
Lead Investigator: Professor Reg Dennick, Professor of Medical Education, Assistant Director of Medical Education Unit
Co Investigators: Ebtihaj Nafea, PhD Student, Ana Linda Da Silva, PhD Student School of Community Health Sciences.

Thank you for your letter dated 24th November 2011 notifying the Committee of a minor amendment to this study as follows:

Amendment no 1 24/11/2011

- To extend this study to include dental students in three Dental Schools: 2 in the UK and one in Saudi Arabia. The format and protocol of the research remains exactly the same but the clinical reasoning test will be modified to have a dental content.
- Addition of a new full-time PhD student undertaking this research: Ebtihaj Nafea.

These have been reviewed and are satisfactory and the amendment request no 1 is acknowledged.

Approval is given on the understanding that the Conditions of Approval set out below are followed.

Conditions of Approval

You must follow the protocol agreed and any changes to the protocol will require prior Ethics' Committee approval.

This study is approved for the period of active recruitment requested. The Committee also provides a further 5 year approval for any necessary work to be performed on the study which may arise in the process of publication and peer review.

You promptly inform the Chairman of the Research Ethics Committee of

(i) Deviations from or changes to the protocol which are made to eliminate immediate hazards to the research subjects.

(ii) Any changes that increase the risk to subjects and/or affect significantly the conduct of the research.

(iii) All adverse drug reactions that are both serious and unexpected.

(iv) New information that may affect adversely the safety of the subjects or the conduct of the study.

(v) The attached End of Project Progress Report is completed and returned when the study has finished.

Yours sincerely

Dr Clodagh Dugdale
Chair, Nottingham University Medical School Research Ethics Committee

Appendix 2: Screen shots for the CRT (note that numbering of questions in chapter 4 discussion started from the third question question)

Clinical Reasoning Test

Dear Fifth Year Dental Student:
My name is Ebtihaj Nafea. I am a dentist and PhD student at the University of Nottingham. For my PhD research, I am assessing clinical reasoning among undergraduate dental students at four universities(Birmingham, Manchester, KAAU, and Taibah). Because you are a fifth year dental student I am inviting you to participate in this research study by completing the following form.
This study will provide important information and guidelines to dental educators and course planners to improve clinical reasoning skills within the undergraduate dental curriculum.
I would be very pleased if you could spare some time to take part in my research. The following questionnaire will require approximately 10-15 minutes to complete. Please note that for the purposes of my research, it is not always possible to see the previous screen once you have completed it.
Please be assured that all information collected during this research will be kept strictly anonymous and confidential . A summary of the finding of the study will be forwarded to you. In addition, participation is strictly voluntary and you may refuse to participate at any time.
Thank you for taking time to assist my educational endeavors. If you have any questions or concerns, or if I may be of assistance in any way, please do not hesitate to contact me at mcxen3@nottingham.ac.uk
Note: you will have the opportunity to enter a raffle to win Amazon gift vouchers a a thank you for your effort. The first winner will receive £100. Tow second winners each will receive £50. Three third place winners each will receive £25.
Best wishes
Ebtihaj Nafea
PhD student
Medical Education Unit
Medical School
University of Nottingham, UK
NG7 2UH

1. What is your gender?

- Female
- Male

2. The place of your school

- Experts (dentists)
- King Abdul Aziz University
- Taibah University
- University of Birmingham
- University of Manchester

Page 1

Clinical Reasoning Test

CASE 1

A 30-year-old lady came to your dental office complaining of pain related to her lower left molars, especially when biting. She repoted the pain as moderate.

Past medical and dental history:
the patient is medically fit and is not on any medication. She reported that she is used to having regular visits to the dentist. Her last visit to the dentist was about 3 weeks ago.

Extra-oral examination
No abnormality observed.

Intra-oral examination
Fairly good oral hygiene was noticed with healthy gingival tissue. She has class I occlusion with cross bite in her canines on both sides.Class I occlusal composite restorations to her teeth: UR7, UL6, LL7 and LR7. The UR6 has a class I amalgam filling. She also has fissure sealant for her premolars. The LL7, with an adequate occlusal class I composite, was sensitive to vertical percussion. Generalised attrition to occusal surfaces was observed. By asking the patient, she confirmed that she often clenches her teeth especially when stressed.

Radiographic examination
No periapical lesion was noticed in the area of concern.

3. List the features from the case description above that could help you in making a diagnosis for her complaint (List at least three)

1

2

3

4. At this stage, what is your most likely diagnosis for the LL7?

5. What further investigations will help you to diagnose this problem, or confirm your diagnosis?

Clinical Reasoning Test

6. If you suppose that this lady has a high composite filling for LL7, and by reviewing her dental record, it was found that her dentist had used composite for anterior teeth. How can you manage her problem? Choose the best answer.

- Slightly reduce the filling by 0.5mm
- Replace the filling by a new one with composite for posterior teeth
- Do a night gaurd (splint)
- Ignore the problem as it will go away with time, it will undergo attrition by clenching.
- Identify high points and reduce the filling
- Replace the filling with amalgam

7. How could this problem be avoided in the first place?

Clinical Reasoning Test

CASE 2

A 16 year old male came to your clinic complaining of brownish discolouration and irregular teeth related to his anterior teeth as seen in the picture. He is shy and does not want to show his teeth. He also stated that he's had bad teeth since he was a child but he's now started to take care of them and they are improving. His nationality is Indian and he came to live in the UK 8 years ago.

8. What clinical features would you focus on in making your diagnosis for this patient? List up to 3

1

2

3

9. If you could choose the course of action to follow, what would you like to do immediately? (choose one)

- I don't know
- Ask the patient more questions
- Conduct intraoral examination
- Give him oral hygiene instructions and do scaling.
- Take an x-ray
- Refer the patient to an oral pathology specialist

Clinical Reasoning Test

10. From the list below select the (THREE) most important questions that you would like to ask the patient.

- ☐ Do you have other siblings affected?
- ☐ How frequently do you brush your teeth?
- ☐ Do you use fluoridated tooth paste?
- ☐ Do you have any pain or sensitivity?
- ☐ Have you experienced trauma to your teeth?
- ☐ Do you drink lots of coffee or tea?
- ☐ What type of water did you used to drink when you were younger?
- ☐ Did you have any serious illness when you were a baby?
- ☐ Do you use Chlorhexidine mouth wash?

Clinical Reasoning Test

The patient's answers to the previous questions are:
1.How frequently do you brush your teeth? I brush my teeth twice a day.
2.Did you have any serious illness when you were a baby? No I don't think so.
3.Do you use Chlorhexidine mouth wash? Yes I usually use it once a day for about three months.
4.What type of water did you used to drink when you were younger? Tap water.
5.Do you have any pain or sensitivity? No
6.Do you drink lots of coffee or tea? I usually take two cups of black coffee daily.
7.Do you use fluoridated tooth paste? Yes
8.Do you have other siblings affected? I have a 4-year old sister and she hasn't got this problem.
9.Have you experienced trauma to your teeth? Can't remember.

11. Select (THREE) results from the list below that you would expect to find during examination:

- ☐ Generalised discolouration
- ☐ Caries
- ☐ Generalised recession
- ☐ Localised discolouration
- ☐ Open bite
- ☐ Small teeth
- ☐ Loss of proximal contact
- ☐ Abrasion and horizontal bone loss
- ☐ Vertical bone loss
- ☐ Submandibular gland tenderness
- ☐ Family history of a similar condition
- ☐ Gingivitis

Clinical Reasoning Test

12. Choose (THREE) differential diagnoses

- ☐ Generalised enamel abrasion
- ☐ Dentinogenesis imperfecta
- ☐ Extrinsic discolouration
- ☐ Amelogenesis imperfecta
- ☐ Genetic pigmentation
- ☐ Calculus deposition
- ☐ Fluorosis
- ☐ Generalised attrition
- ☐ Enamel hypoplasia
- ☐ Enamel opacities
- ☐ Generalised enamel hypomineralisation

13. The following questions deal with your ability to use the results of investigations to refine your diagnostic hypotheses

Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (Amelogenesis imperfecta), and you find the result of investigation was (generalised brownish discolouration with white patch and pitting of enamel), this hypothesis becomes:

14. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (external stain), and then you find the result of investigation was that (staining of all tooth surfaces for incisors and first molars), this hypothesis becomes:

15. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (tooth fluorosis) and you find the result of investigation was (marked wear), this hypothesis becomes?

Clinical Reasoning Test

16. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (congenital enamel defect), and then you find the result of investigation was (open bite), this hypothesis becomes?

17. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (tooth fluorosis), and you find the result of investigation was that (the patient had used to drink ground water when he was in India), this hypothesis becomes:

18. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (Amelogenesis Imperfecta), and you find the result of investigation was that (both mother and father have similar condition whereas young siblings have not), this hypothesis becomes:

Clinical Reasoning Test

CASE 3

A 53-year-old, non-smoking male came to your clinic complaining of bleeding gums and bad breath. He reported that he visits the dentist only when having toothache. He also reported that he brushes his teeth only once a day and does not use dental floss. He also wanted to replace his missing teeth.

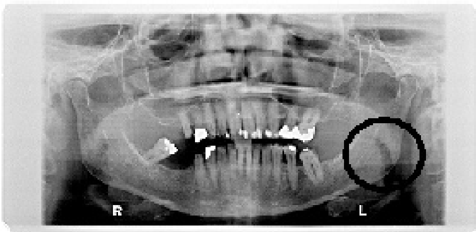
19. At this stage, what do you think are the possible causes for his symptoms (please provide TWO causes)

1

2

Clinical Reasoning Test

(Past medical history)
In the review of symptoms he reported mild fatigue. He also reported that his father died of a heart attack at the age of 66 and his mother was alive and taking medication for diabetes mellitus. He reported recent weight loss, but you notice central obesity.
(Past dental history)
The patient reported that in the past he had required many fillings and had a lot of teeth extracted.
(Intra oral examination)
Examination reveals multiple missing teeth with several amalgam restorations. The gingiva demonstrated moderate to severe inflammation, being more pronounced in the papillae. Periodontal abscesses and moderate plaque accumulations were present. Probing depth ranged from 2 to 8 mm and the remaining molars have furcation involvements and variable degrees of mobility.
This is the OPG of the patient



20. Based on the information provided, what is your most probable diagnosis of his periodontal problem?

21. Referring to the picture, please provide a suitable diagnosis to the radiopacity in the left angle of the mandible.

22. You offer endodontic treatment and crowns for multiple teeth, and then do a removable partial denture. However, the patient tells you that he cannot afford the cost of this comprehensive treatment. He suggests that you extract his remaining teeth and do a complete denture. You also need to do a complete denture in order to finish your course requirements. What can you do in this case?

Clinical Reasoning Test

A few weeks after giving oral hygiene instructions, scaling and root planing, and endodontic treatment for UR4 and LR5 you notice the oral hygiene has improved but tissue inflammation remains. You decide to refer the patient to a periodontist. The specialist performs surgical periodontal treatment in the maxillary right quadrant. The healing response is fair with persistence of inflammation of the gingival tissue even in the treated area. A few months later the patient underwent another surgical treatment to the maxillary left quadrant which was similar to the first surgical procedure. Unfortunately, the post surgical course was as before and both surgical treatments were unsuccessful with persistant inflammation.

23. What do you think is the possible cause of the unimproved periodontal condition?

Clinical Reasoning Test

CASE 4

24. A lady rushes into your emergency dental clinic with her 4-year old daughter who is crying and has blood drooling from her mouth.
What are the possible causes for her problem?

1.
2.

25. What investigations will help you to specify the possible causes?

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Clinical Reasoning Test

The mother reported that her daughter had accidentally fallen on her face and she took her child straight away to your clinic.

26. You conduct an intraoral examination and find that crowns of both upper primary central incisors are palatally displaced but quite firm in this position.
Your most likely management will include: (CHOOSE TWO)

- ☐ • Extraction of both upper centrals, since they are deciduous
- ☐ • Trying to pull them back to their position
- ☐ • Leave them if not interfering with occlusion
- ☐ • Refer the patient to a maxillofacial surgeon
- ☐ • Take an x-ray

27. If these teeth had been intruded apically how would this change your management plan?

Clinical Reasoning Test

CASE 5

This is a picture of a seven-year old boy who came to your dental office with his parents. His dad was concerned with his son's front teeth which had the lesion shown in the photograph.

28. How would you describe this lesion?

29. What are the differential diagnoses of this lesion? (LIST UP TO TWO)

1

2

30. The following questions deal with your ability to use the results of investigations to refine your diagnostic hypotheses. Use the Likert scale to indicate how likely this hypothesis becomes.

If your diagnostic hypothesis was (localised gingival inflammation), and then you find the result of investigation was that (the patient was playing with a pencil in his mouth), this hypothesis becomes:

31. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (genetic gingival pigmentation), and then you find the result of investigation was that(the mother has got genetic pigmentation), this hypothesis becomes:

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Clinical Reasoning Test

32. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (eruption cyst), and then you find the result of investigation was that(this lesion is slightly painful upon palpation), this hypothesis becomes:

33. Use the Likert scale to indicate how likely this hypothesis becomes

If your diagnostic hypothesis was (euption haematoma), and you see the periapical film of the patient below, this hypothesis becomes:

34. Please enter your email address to take part in the raffle.

35. We would like to conduct qualitative research about clinical reasoning using interviews. We would like you to volunteer for our qualitative research. If you are a Birmingham dental student and happy to be interviewed(less than 20 minutes), could you please provide your email address below. Compansation for your time will be provided for you

Appendix 3: CRT marking

Question Number	Question type	Total mark
Q1	Open-ended	3
Q2	Open-ended	1
Q3	Open-ended	1
Q4	MCQ	1
Q5	Open-ended	1
Q6	Open-ended	3
Q7	MCQ	1
Q8	MCQ	3
Q9	MCQ	3
Q10	MCQ	3
Q11	MCQ	1
Q12	MCQ	1
Q13	MCQ	1
Q14	MCQ	1
Q15	MCQ	1
Q16	MCQ	1
Q17	Open-ended	2
Q18	Open-ended	1
Q19	Open-ended	1
Q20	Open-ended	1
Q21	Open-ended	1
Q22	Open-ended	2
Q23	Open-ended	1
Q24	MCQ	2
Q25	Open-ended	1
Q26	Open-ended	1
Q27	Open-ended	2
Q28	MCQ	1
Q29	MCQ	1
Q30	MCQ	1
Q31	MCQ	1

Appendix 4: Information letter and consent for students

UNIVERSITY OF NOTTINGHAM MEDICAL SCHOOL ETHICS COMMITTEE

Information sheet for Normal Healthy Volunteers

Title of Project: Clinical Reasoning in Dental Students

Name of Investigator*:* Ebtihaj Nafea
(PhD Student School of Community Health Sciences)

Name of Supervisors*:*
Prof Reg Dennick (School of Community Health Sciences)
Dr Mohsen Tavakol (Medical Education Unit)

Healthy Volunteer's Information Sheet

Dear Dental Student,

You have been invited to take part in a research study. Before you decide whether to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and decide whether you wish to take part or not.

Background

This study is being done as part of my PhD project which aims to explore the impact on the development of clinical reasoning of different educational strategies used among different types of dental schools.

What is the project about?
This project is concerned with research into how dental students learn about and practice clinical reasoning and the curriculum factors that might influence its acquisition. It consists of a quantitative and qualitative methodology. The quantitative aspect will deliver an on-line clinical reasoning test to students to measure their ability to diagnose and describe how they would manage some common clinical problems. The qualitative aspect will involve an interview during which the student will describe their own understanding of clinical reasoning and how they have acquired the skill plus they will be asked to 'talk through' a typical clinical problem. We hope that as many students as possible will take the on-line test and that some students will also volunteer to be interviewed.

How will I benefit?
After taking the clinical reasoning test and after it has been processed and analysed you will be able to log-on to it again and see the score you achieved and read the recommended answers to the questions. Therefore I hope you will learn something. In addition you will be contributing to a greater understanding of how students learn and understand clinical reasoning processes which hopefully will improve educational practices in the future.

What will the researcher be doing?
I will take care to safeguard the anonymity and interests of all students participating. Only the researcher will have access to the data. The score you obtain and the information you reveal in the interviews will not in any way be given to your dental school and it will of course have no impact on your progress or degree classification.

- All final year students will be offered an on-line test and if you agree to participate in the project you will be able to take it.
- Some students will volunteer to be interviewed for one hour by the researcher
- Generic demographic data will be collected, but anonymity of the participants will be kept.

What happens to the information you provide?

It will be used only for this research. Only the investigator and her supervisors will have access to the information recorded. I will not identify any individuals in the reports/papers I produce. All data will be anonymised and stored on secure password protected servers in the University of Nottingham.

Where can you get more information about the project?
The lead investigator will be available to answer any questions you may have relating to this project.

Why have you been chosen?

You are a final year dental student in a well established dental school with a well recognised curriculum framework. The investigator will be doing the same research in other dental schools.

Do you have to take part?

Participation in this research project is entirely voluntary. It is up to you to decide whether or not to take part. If you do decide to take part you will give your consent by completing the on-line test and returning it to the researcher. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What if something goes wrong?
If you have any complaint about the research, you should initially approach the lead investigator and if no satisfactory outcome is achieved then you should contact the Chair of the Medical School Ethics Committee at the University of Nottingham.

Lead Investigator:
Ebtihaj Nafea
PhD Student School of Community Health Sciences
Email: mcxen3@nottingham.ac.uk
Medical Education Unit, Medical School University of Nottingham, Nottingham NG7 2UH,
Tel (44) 0115 823 0013,
Fax (44) 0115 823 0014

Supervisor of the Project:
Prof Reg Dennick
Email: reg.dennick@nottingham.ac.uk
Medical Education Unit, Medical School University of Nottingham,
Nottingham
NG7 2UH,
Tel (44) 0115 823 0013,

Co-supervisor
Dr Mohsen Tavakol
Email: mohsen.tavakol@nottingham.ac.uk
Medical Education Unit, Medical School University of Nottingham,
Nottingham
NG7 2UH,
Tel (44) 0115 823 0218,

Chair of the Medical School Ethics Committee:
Dr Clodagh Dugdale
Ethics Committee
Division of Therapeutics and Molecular Medicine
D Floor, South Block
Queen’s Medical Centre
Nottingham
NG7 2UH

Who is organising and funding the research? The research is being carried out by Ebtihaj Nafea as part of her PhD thesis.

No funding has been received for this research project.

Who has reviewed the study? This study has been approved by the University of Nottingham Medical School Ethics Committee.

Contact for Further Information

Ebtihaj Nafea

PhD Student School of Community Health Sciences
Email: mcxen3@nottingham.ac.uk

Appendix 5: Information letter to experts

Dear colleague,

My name is Ebtihaj Nafea. I am a dentist and a PhD student at the University of Nottingham. I am studying clinical reasoning in undergraduate dental students. As part of my study I have developed an online tool for the assessment of clinical reasoning skills. I would really appreciate it if you can help me and take part in validating this tool. Your response as an expert will help me check the construct validity of the test.

This test takes about 15 to 20 minutes to complete. Results are anonymous and only I and my supervisors can have access to the recorded data. Could you please use the link below and the password provided to take part in this test? Please ignore questions asking about the location of your university and providing your email address because they are designed for the students. Thank you in advance for your help.

http://www.psychometricanalysis.net/cr.php

Password is: student13

Kind regards

Ebtihaj Nafea

Appendix 6: Instructions for think-aloud method

The purpose of this study is to explore clinical reasoning in final year dental students. I want you to review vignettes about a real case and tell me what you would do so I can hear how you address each vignette.

Please note that this is not a test of your clinical knowledge or of treatment planning, but rather my attempt to understand how you think when you encounter a clinical situation.

At any point through this interview, if you think that you need any additional information, please ask for it. Any information will be provided to you only if you think that is needed.

Appendix 7: Samples of the emergent themes, copied from QSR NVivo10®

The following table presents '*Methods of Learning Clinical Reasoning'* code as an example of the data coding carried out for the qualitative study (presented in Chapter 5).

Didactic courses (lectures)	<Internals\\Taibah 2> - § 1 reference coded [1.75% Coverage] Reference 1 - 1.75% Coverage We have two courses, "Diagnosis 1" - "Oral Diagnosis 1" and "Oral Diagnosis 2" <Internals\\Taibah 3> - § 1 reference coded [0.98% Coverage] Reference 1 - 0.98% Coverage Mostly I learned in CC course in the final year course. <Internals\\Birmingham 2> - § 2 references coded [6.30% Coverage] Reference 1 - 2.37% Coverage I think mostly from lectures when they teach us about the different diseases and what tests we can do to each, like, certain diagnosis and things like that. That was mostly it. Reference 2 - 3.93% Coverage Okay. Well, I might like to learn about the caries and things like that, we had a series of lectures about the different types of caries like occlusal interproximal, what the aetiology is and, kind of like, and then the management afterwards and how the patient presents, and things like that. <Internals\\Birmingham 3> - § 1 reference coded [4.39% Coverage] Reference 1 - 4.39% Coverage I think we have had lectures where, for example, we had a lecture on different options for treating the dental … for a space closure, different options for space, so obviously they showed implants, bridge, leave the space, not do anything, so there is a sort of … there were different options that we had, so that was sort of like what they taught us. <Internals\\Birmingham 4> - § 2 references coded [7.44% Coverage] Reference 1 - 1.87% Coverage By different like… Through all our lectures really, through everything that we've learnt, it all like encompasses together. To like have Clinical Reasoning you need like a general knowledge? Reference 2 - 5.57% Coverage but I think clinically, like practically, when you see a situation in front of you and you've been learning from just your clinician, and seeing their methodology and the way that they think things through, enables you to establish your own clinical reasoning from that. I think for me anyway, like I know a lot of people get information from lectures but I feel like the way… When you see someone else going through that reasoning in your head and you can understand their logicality and their process of thought, that enables me a lot to go through something like that myself. <Internals\\Birmingham 5> - § 1 reference coded [2.28% Coverage] Reference 1 - 2.28% Coverage I think mostly through lectures, so being taught that say this set of symptoms, or these signs, usually correlate with a certain disease or outcome or cause, or aetiology, and that's done through lectures. <Internals\\Birmingham 6> - § 2 references coded [3.02% Coverage] Reference 1 - 1.36% Coverage then you get different lectures about communicating with patients, and professionalism and everything, Reference 2 - 1.66% Coverage

	Well like in lectures we get lectures on different things, so they might talk through a case so, you know like a practice case <Internals\\Taibah 2> - § 1 reference coded [0.36% Coverage] Reference 1 - 0.36% Coverage Just lectures. <Internals\\Taibah 4> - § 1 reference coded [0.73% Coverage] Reference 1 - 0.73% Coverage Learning? By… the lectures, the lecture <Internals\\Manchester2> - § 1 reference coded [100.00% Coverage] Reference 1 - 100.00% Coverage along with lectures and information we get from lectures <Internals\\Manchester3> - § 1 reference coded [100.00% Coverage] Reference 1 - 100.00% Coverage Also in lectures <Internals\\Manchester5> - § 2 references coded [100.00% Coverage] Reference 1 - 100.00% Coverage lectures Reference 2 - 100.00% Coverage Like we learn it from lectures
Evidence-based learning	<Internals\\Manchester1> - § 1 reference coded [100.00% Coverage] Reference 1 - 100.00% Coverage In Manchester we do inquiry-based learning <Internals\\Manchester2> - § 2 references coded [100.00% Coverage] Reference 1 - 100.00% Coverage Another way and the best way without a doubt is to look at randomised control trials and systematic reviews of studies and see what the outcomes have been. So whether it's to replace a filling or repair a filling. Reference 2 - 100.00% Coverage access a randomised control trial and read it and look at the conclusions which were drawn from this trial. These sort of trials are made to be as unbiased as possible. So they are as fair as possible. And by doing that you get a fair and proper outcome. So that's probably one of the best ways I think. <Internals\\Manchester3> - § 3 references coded [100.00% Coverage] Reference 1 - 100.00% Coverage We've also learnt clinical reasoning by doing things as simple as CATs. So Critical Appraisal Topics which have helped us understand how important it is for like strong evidence Reference 2 - 100.00% Coverage How important it is to differentiate between what's strong evidence and significant differences between different things. Reference 3 - 100.00% Coverage One of the things that I learnt was in my critical appraisal topic I set about a question which was is the use of clorhexidine, perioperative use of it, beneficial in reducing albela osteitis following

	mandibular third molar extractions. Whilst reading a lot of books and stuff it tells you that it's really, really good for patients to rinse out with clorhexidine. It reduces the chance of dry socket. When I did my critical appraisal topic and looked at all the different amount of data, appraised it, had a look at it, it turns out that there wasn't a significant difference at all which helped me come to the understanding that it doesn't have a significant difference. It isn't needed. Then so when my patient asks, 'Will I need something else?', this is when I was doing extractions, that could help reduce the chance of getting the infection, I didn't turn around and say, 'Yeah. We can give you perioperative use of clorhexidine', because there's no significant difference for it. <Internals\\Manchester4> - § 1 reference coded [100.00% Coverage] Reference 1 - 100.00% Coverage You might go away and research, have a look at different papers that might have been published like systematic reviews, cohort studies, things like that.
Experience of colleagues and tutors	<Internals\\Birmingham 4> - § 1 reference coded [5.57% Coverage] Reference 1 - 5.57% Coverage but I think clinically, like practically, when you see a situation in front of you and you've been learning from just your clinician, and seeing their methodology and the way that they think things through, enables you to establish your own clinical reasoning from that. I think for me anyway, like I know a lot of people get information from lectures but I feel like the way... When you see someone else going through that reasoning in your head and you can understand their logicality and their process of thought, that enables me a lot to go through something like that myself. <Internals\\Taibah 1> - § 1 reference coded [0.94% Coverage] Reference 1 - 0.94% Coverage experience of colleagues, of dental colleague or <Internals\\Birmingham 1> - § 1 reference coded [1.73% Coverage] Reference 1 - 1.73% Coverage You are taught it on clinical practice as an everyday – when a patient comes to you, a clinician will talk through treatment planning with you and how to approach it <Internals\\Birmingham 5> - § 1 reference coded [2.63% Coverage] Reference 1 - 2.63% Coverage and then through the staff themselves, because they'll tell you how they will have reached that decision. Yeah, like what signs and things that they look for, like what special tests and investigations you need to reach those decisions. <Internals\\Manchester 7> - § 1 reference coded [2.40% Coverage] Reference 1 - 2.40% Coverage Then you have your own patients that you work on, who you can go and consult it with your consultants and your tutors and everything like that, and that can help you a lot. <Internals\\Manchester1> - § 2 references coded [100.00% Coverage] Reference 1 - 100.00% Coverage on-clinic, in that a tutor would ask us what we think and then they'd critique how we've come to our diagnosis and then so you learn for next time kind of thing rather than sort of having lectures on it, Reference 2 - 100.00% Coverage the tutor comes in and you present the patient, present your findings, and what you think the diagnosis is. Then the clinician kind of questions you and you come together and then you learn better clinical reasoning for next time because you learn more through experience and what the special tests mean and what you can take from it. <Internals\\Manchester5> - § 2 references coded [100.00% Coverage]

	Reference 1 - 100.00% Coverage and different tutors Reference 2 - 100.00% Coverage People downstairs in the clinic