DEVELOPING, IMPLEMENTING AND EVALUATING THE EFFECTIVENESS OF AN UNDERGRADUATE CLINICAL REASONING CURRICULUM

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ABSTRACT

BACKGROUND

Clinical reasoning (CR) is a recursive, multidimensional, and complex process involving informal and formal strategies for the analysis and evaluation of patients' information. CR skills are traditionally acquired through the experiential learning of undergraduate (UG) students during the curriculum. Recently there has been an acknowledgement of the need to explicitly teach CR. The University of Nottingham (UoN) aimed to introduce a vertically integrated CR theme. The opportunity provided by this development was used to develop, implement and evaluate this CR curriculum.

AIMS AND OBJECTIVES

The following research questions were formulated:

1. Is CR being embedded explicitly in the curriculum?
2. How effective is this new curriculum in developing CR skills for students and teaching skills for teachers?
3. How do students learn/develop CR?
4. Does the phase of the curriculum influence the development of CR?
5. Does the curricular model influence the development of CR?
6. Does gender have any effect?

METHODOLOGY

The researcher was involved in the planning, development, implementation, and evaluation of the curriculum. Both quantitative and qualitative methodologies were employed.

- The effectiveness of the CR resources, the impact of different curricular models, the phase of the curriculum and the influence of gender was measured and compared by summative assessments.

- Interviews were used to discover the CR understanding of students and teachers and to analyse learning needs.

Results

1. The CR theme was explicitly embedded in the curriculum.
2. This curriculum was effective in developing CR skills for students and in developing the teaching skills of teachers.
3. Qualitative research revealed how students learned and developed their CR skills.
4. The curricular phase had an impact on the development of CR.
5. PBL students scored better than integrated students in the summative exam at CP1. This was not found at CP3.
6. Gender had no influence on CR.

Conclusions

This study contributes to the body of knowledge regarding the development, implementation and evaluation of a CR curriculum. Despite the problems associated with working with a live curriculum a CR component was successfully developed and evaluated by means of qualitative and quantitative methods. The results of the qualitative study, in particular, have contributed to the further development of the CR curriculum and have changed our educational practices.

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DEDICATION

I dedicate this book to my husband, my parents and my children.

LIST OF PUBLICATIONS AND PRESENTATIONS

PUBLICATIONS

Evaluating perceptions of teaching the teachers about clinical reasoning
S Khin-Htun, R Dennick, N Cooper, BMJ Simulation and Technology Enhanced Learning Nov 2017, 3 (Suppl 2) A 62-A63; doi:10. 1136/bmjstel-2017-asphihconf.129

A Qualitative Study Exploring the Relationship of Curricular Models to the Development of Clinical Reasoning Skills Among Medical Students
Dr. S. Khin-Htun, A Kushairi. CPQ Medicine (2018) 1:1, Research Article, Published 8 May 2018

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S; Khin-Htun, R Dennick, Journal of Health Science & Education, eSciRes JHSE-1-138, Vol 2(3), 2018: DOI: 10.0000/*JHSE*.1000138

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S Khin-Htun, A Kushairi, Medical Teacher, October 2018 https://doi.org/10.1080/0142159X.2018.1502418

Is Clinical Reasoning Assessed in Examinations? A Qualitative Study on Student Perceptions.
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Effect of Different Curricular Models on the Development of Clinical Reasoning Skills among Medical Students: a Quantitative Study
Khin-Htun S, Thu K, (2018). J Health Sci Educ 3(1): 154. doi: 10.0000/*JHSE*.1000154 https://escires.com/articles/Health-1-154.pdf

The Effect of Curricular Phase on the Clinical Reasoning Skills of Medical Students at the University of Nottingham
Khin-Htun S, Coles J, 2019, MedEdPublish, 8, [1], 43, https://doi.org/10.15694/mep.2019.000043.1

How effectively are we training our teachers to teach clinical reasoning?
Khin-Htun S, Hickman, J, Glover, I, (2019). *J Health Sci Educ* 3(2): 156. DOI: 10.0000/*JHSE*.1000156

Comment on "A student's perspective on developing clinical reasoning (CR) skills"

S Khin-Htun, A Kushairi, Medical Teacher, Journal: *Medical Teacher* (IMTE) Accepted, Article ID: IMTE 1595368,
https://doi.org/10.1080/0142159X.2019.1595368

PRESENTATIONS

International

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
ASME, Association for the Study of Medical Education
July 2014, Annual Scientific Meeting

Presentation of "Differences between PBL students and Integrated curriculum students in developing clinical reasoning" (Oral)
ASME, Association for the Study of Medical Education
July 2015, Annual Scientific Meeting

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
DEMEC, Developing Excellence in Medical Education Conference
Nov 2015

Presentation of "Update on Developing and Implementing clinical reasoning curriculum" (oral)
ASME, Association for the Study of Medical Education
July 2016, Annual Scientific Meeting

Presentation of "Exploring the view of medical students towards Clinical reasoning teaching at the University of Nottingham" (poster)
DEMEC, Developing Excellence in Medical Education Conference
Nov 2017

Presentation of "Evaluating Perceptions of Teaching the Teachers About Clinical Reasoning" (poster)
ASPiH, Association for Simulated Practice in Healthcare
Nov 2017

Presentation of "How effectively are we training our teachers to teach clinical reasoning" (Poster: accepted)
ASME, Association for the Study of Medical Education
July 2019, Annual Scientific Meeting

National

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
Achieving Excellence in Surgical Training conference Birmingham
The Royal College of Surgeons of Edinburgh
Oct 2015

Presentation of "Developing, Implementing and evaluating the effectiveness clinical reasoning curriculum" (oral)

CRÈME, Clinical Reasoning in Medical Education
June 2016

Presentation of "Exploring the view of medical students towards Clinical reasoning teaching at the University of Nottingham" (poster)
CRÈME, Clinical Reasoning in Medical Education
Nov 2017

Regional

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
MERG meeting (Medical Education and Research Group)
July 2013

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
University of Nottingham, School of Medicine Launch day
Dec 2013

Presentation of "Developing and Implementing clinical reasoning curriculum" (oral)
FERG, (Faculty of Education and Research Group) University of Nottingham
July 2014

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
NUMEC (Nottingham University Medical Education Conference)
1st annual Research and Teaching event
July 2014

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
FERG, (Faculty of Education and Research Group) University of Nottingham
July 2016

Presentation of "Developing and Implementing clinical reasoning curriculum" (poster)
NUMEC (Nottingham University Medical Education Conference)
2015

Presentation of "Developing and Implementing clinical reasoning curriculum" (oral)
UMED (Undergraduate Medical Education Department, QMC, NUH NHS Trust)
2nd annual Research and Teaching event
July 2016

Presentation of "Exploring awareness of teaching staff towards clinical reasoning teaching" (oral)
UMED (Undergraduate Medical Education Department, QMC, NUH NHS Trust)
3rd annual Research and Teaching event
July 2017

Running workshop on "How shall we change our educational practice to improve students' clinical reasoning?" (oral)
UMED (Undergraduate Medical Education Department, QMC, NUH NHS Trust)
4rd annual Research and Teaching event
July 2018

Local

Poster Presentation and display of developing and implementing a clinical reasoning curriculum in undergraduate medical education
Medical School Seminar, University of Nottingham
2013

Poster Presentation and display of developing and implementing a clinical reasoning curriculum in undergraduate medical education
TSCSC (Trent Simulation and Clinical Skills Centre, QMC, NUH NHS Trust)
2014

Presentation and display of our centre for Health Education East Midlands Visit
TSCSC (Trent Simulation and Clinical Skills Centre, QMC, NUH NHS Trust)
2014

Fellow Project Presentation of Evaluating a Clinical Reasoning Curriculum in CP1
TSCSC (Trent Simulation and Clinical Skills Centre, QMC, NUH NHS Trust)
2015

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LIST OF ABBREVIATIONS

2+2 Curriculum	2 preclinical years followed by 2 clinical years
A-level	Advanced level
ACE	Advanced Clinical Experience
AMC	Academic Medical Centre
ANOVA	Analysis of Variance
ASN	Alimentary system and Nutrition
BCS	Basic and clinical Sciences
BMBS	Bachelor of Medicine Bachelor of Surgery degree
BMedSci	Bachelor of Medical Sciences
CBD	Case Based Discussion
CCS	Clinical Case Scenario
CEX	Clinical Evaluation Exercise
CI	Competence index
CIP	Comprehensive Integrative Puzzle
CP	Clinical phase
CR	Clinical Reasoning
CRH	Cardiovascular, Respiratory and Haematology
CRP	Clinical Reasoning Problems
CRTs	Clinical Reasoning Tests
CReME	The UK Clinical Reasoning in Medical Education group
CTT	Classical Test Theory
D study	Inform decisions
DTI	Diagnostic Thinking Inventory
EBM	Evidence based medicine
ECPD	Early Clinical & Professional Development Course

ED	Emergency Department
EMI	Extended Matching Items
FY	Foundation year
F1	Foundation year 1 doctor
G	Generalizability
GAMSAT	The Graduate Australian Medical School Admissions Test
GCSE	General Certificate of Secondary Education
GEM	Graduate Entry Medicine
GMC	General Medical Council
GP	General Practitioners
H	Hypothesis
HDU	High Dependency Unit
HDT	Human Development and tissue differentiation
HE	Higher Education
HYMS	Hull York Medical School
ID	Item discrimination index
IFME	The integrated Foundation in Medical Education
IRT	Item Response Theory
KFE	Key-features exam
MACCS	Mandatory assessment of Core Clinical Skills
MAST	Medical Assistantship Placements
MAU	Medical Assessment Unit
MCQ	Multiple choice questions
MEQ	Modified essay questions
MMI	Multiple Mini Interview
MMR	Mixed methods research

MSCAA	Medical Schools Council Assessment Alliance
NBEO	National Board of examiners in Optometry
NHS	National Health Service
NIHR	The National Institute of Health Research
NLE	Network Learning Environment
NUH	Nottingham University Hospitals
OMP	One-Minute Preceptor
OSCE	Objective structured Clinical Examination
OSLAR	Objective structured long examination record
PBL	Problem based learning
PDCA	Plan, Do, Check and Act
PDDE	Plan, Develop, Deliver, Evaluate
PMP	Patient Management Problems
QMC	Queen Medical Centre
RCGP	The Royal College of General Practitioners
RCSEng	The Royal College of Surgeons, England
REN	Renal and Endocrine systems
RQ	Research questions
SAC	Structured Academic Controversy
SAQ	Short Answer Question
SAU	Surgical Assessment Unit
SCP	Surgical care Practitioner
SCR	Scientific Basis of Clinical Reasoning
SCT	Script Concordance test
SDMEG	The Scottish Deans' Medical Education Group
SEM	Standard error of the measurement
SIFT	Service Increment for Teaching

SP	Simulated patients
SPSS	Statistical Package for the Social Sciences
SPT	Second Primary tumours
SRL	Self-regulated learning
SSM	Special Study Module
TDS	Test of Diagnostic skills
TF	Teaching Fellow
TTP	Transition to Practice
UCL	University College London
UCAS	The Universities and Colleges admission service
UG	Undergraduate
UGCC	Undergraduate Curriculum Committee
UKCAT	UK Clinical Aptitude Test
UMED	Undergraduate Medical Education department
UoN	University of Nottingham
USMLE	United States Medical Licensing Examination
VLP	Virtual learning patients
VLE	Virtual learning environments

CHAPTER 1 INTRODUCTION

Clinical reasoning (CR) is an important skill for medical practitioners (Cooke, Irby, Sullivan, & Ludmerer, 2007; Stewart & Wubbena, 2015). However, CR was not a part of formal instruction in the past (Norman, 2005; Higgs & Jones, 2008). Moreover, little work has been done to understand how it is being taught at an undergraduate (UG) level (Harendza et al., 2017). This study focuses on the planning, design, and implementation and evaluation of a CR-oriented curriculum among UG students at the University of Nottingham (UoN) to provide a clearer understanding of different curriculum designs to the efficiency of CR training and instruction.

In this chapter, the researcher provides an overview of the study, discussing general information about the topic of CR. This chapter also includes a statement of the problem, as well as an overview of the research methodology, research aims, and research questions. The researcher also briefly discusses the structure and purpose of the thesis and outlines the organization of remaining chapters.

1.1. BACKGROUND

CR describes the thinking and decision-making processes associated with clinical practice (Cooper & Frain, 2016). It also has been defined as the ability to incorporate different types of knowledge, assess critical evidence, and gain insight on the process for arriving at a diagnosis (Naveed & Bhatti, 2017). Improving the critical thinking and CR skills of medical practitioners is crucial to the quality of the outcomes for their patients in practice (Dale & Dale, 2017). Therefore, medical schools and regulatory bodies place priority on the ability to use knowledge effectively and to integrate knowledge more efficiently (Cooke et al., 2007; Stewart et al., 2015). In response to this goal, there have been many innovations in the medical education and curriculum development surrounding CR over the past 100 years

(Cooke et al., 2007). Rencic, Trowbridge, and Durning (2015) stated that the broad and fundamental nature of CR means that it should be treated as a foundation science like anatomy and physiology and that it must be explicitly integrated into various courses throughout UG training.

Researchers suggested that the way students learn might have an important influence on the development of their CR skills (Anderson, Peterson, Tonkin, & Cleary, 2008; Medin, Altom, & Murphy, 1984; Naumann et al., 2016; Patel, Groen, & Norman, 1993; Schmidt, Dauphinee, & Patel, 1987). While some studies have suggested that the curriculum has a minimal effect on the CR development of students, other studies have shown that the UG curriculum has a significant impact on CR skills development (Nafea, 2015). CR courses implemented within the curriculum of medicine also have been found to lead to self-perceived increase in CR skills and to more structure case presentation among participating students (Harendza et al., 2017). Harendza et al. (2017) further emphasized that the longitudinal implementation of CR in medical curricula accompanied by faculty training has the potential to improve CR skills among medical students.

Responding to recommendations on curriculum content from the General Medical Council (GMC), the UoN Medical School proposes to introduce a vertically integrated CR strand starting in Year 1 and working its way through the whole five years of the curriculum. That curriculum will be reinforced by the students' clinical experience, which is expected to prepare them more effectively for qualification. UoN has two curricular cohorts: an integrated curriculum group and a problem-based learning (PBL) curriculum group. Further details of the way CR is embedded in the curriculum, where it would fit, and how to link to the existing program and designing, delivery, resources and barriers will be presented in the third chapter. Although CR

skills are acquired by the experiential learning of UGs as they pass through the clinical curriculum, it has not been formally taught in the past. The absence of this CR training as a specific theme within the curriculum leads to a situation where newly qualifying doctors have varying knowledge and experience about clinical cognition and are relatively unprepared for how best to manage risks.

1.2. STATEMENT OF THE PROBLEM

Despite the importance given to CR in universities globally, studies have shown that CR continues to be taught explicitly only to a small extent, with few studies addressing the implementation of CR courses in UG medical training (Harendza et al., 2017). The research problem that this study seeks to address is the lack of knowledge regarding the development of CR and CR awareness among students at the UG level. Although the term CR 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 et al., 2008).

Furthermore, many of the studies conducted to find the impact of the curriculum on the development of CR were focused on comparing the traditional curriculum with only one type of non-traditional curriculum, which is PBL (Dolmans, Michaelsen, Merrienboer, & Van der Vleuten, 2015; Findyartini, Hawthorne, McColl, & Chiavaroli, 2016; Neufeld, Norman, Feightner, & Barrows, 1981; Servant & Schmidt, 2016; Stanczyk, Hruskocy, Houston, & Ligeikis, 2015). Only a few studies considered the other widely used type of curriculum, the integrated model, in addition to the problem-based and traditional curricula. There is also a need to find out what factors can affect the development of this important skill and to understand what strategies could help students develop their reasoning skills (Groves, 2002; Anderson,

2006). Furthermore, the literature lacks developmental or longitudinal studies aimed at understanding the development of CR at UG level.

1.3. PURPOSE OF THE STUDY

The main focus of this mixed methods study was to evaluate how CR is being developed and integrated into the UoN curriculum for the UG medical degree. The study also addressed the gap in the literature in regard to the impact of different curriculum designs to how students learn and develop CR skills. Evaluating whether CR is explicitly embedded into the curriculum was a key part of this study, with a focus on gathering data on what is occurring in the curriculum.

1.4. RESEARCH QUESTIONS

To achieve the goals of this study, the following research questions were developed:

RQ1. Is CR being embedded explicitly in the curriculum?

RQ2. How effective is the new curriculum in developing the CR skills of the students and in developing the CR teaching skills of the clinical teachers?

RQ3. How do the students learn/develop CR?

RQ4. Does the curricular phase of the curriculum have an impact on the development of CR?

$H0_1$: There is no significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

Ha_1: There is a significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

RQ5. Does the participation in clinical case scenario (CCS) CR teaching curriculum model influence outcomes as measured by summative written exams?

$H0_2$: There is no significant effect from the participation in CCS CR teaching.

Ha_2: There is a significant effect from the participation in CCS CR teaching.

RQ6. Does the redesign of the course each year improve the performance CR?

$H0_3$: There is no significant effect from the CR teaching/implementation process.

Ha_3: There is a significant effect from the CR teaching/implementation process.

RQ7. Does gender influence outcomes as measured by summative written exams?

$H0_4$: There is no significant effect from gender on outcomes as measured by CR score in the summative written exams.

Ha_4: There is significant effect from gender on outcomes as measured by CR score in the summative written exams.

RQ8. Do graduate entry PBL students receive better CR score than UG integrated students?

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

1.5. NATURE OF THE STUDY

Because the research focused primarily on studying the planning, development, and implementation processes of the CR curriculum as well as on devising and using tools to measure and evaluate the effectiveness of the curriculum and its elements, the researcher employed a mixed methods approach. Pragmatism was the paradigm the researcher chose to underpin this current research, given CR's complexity. The researcher opted to enhance the inquiry by mixing both qualitative and quantitative methodologies. According to Almpanis (2016), the mixed methods research (MMR) paradigm integrates quantitative and qualitative research approaches when the research topic belongs to paradigms that are underpinned by the goal to improve on findings of both quantitative and qualitative methods. He further noted that pragmatism, which is the philosophical underpinning for the MMR paradigm, focuses its attention on a situation and the utilization of multimodal approaches to understand that situation. Pragmatism thus allows the matching of epistemological findings to ontological ones and is applicable for studying the breadth and depth of institutional practices (Almpanis, 2016).

In this study, the researcher was involved in all the steps of the curriculum design process as part of the curriculum committee. The piloted design was evaluated for effectiveness in improving the knowledge of the students through increasingly challenging summative tests. Evaluating whether CR is explicitly embedded into the curriculum was a key part of this study. One of the principles of curriculum

evaluation emphasizes the gathering of data on what is occurring in the curriculum. Curriculum effectiveness can be measured via student and staff feedback questionnaires and also based on student performances on the summative exams.

Finally, experts reviewed the summative knowledge paper questions for clinical phase one (CP 1) and clinical phase three (CP 3) of the study, identifying those with CR components. By comparing the results of those questions in summative knowledge-based exams, the researcher attempted to measure the effectiveness of the new CR curriculum in developing CR skills and to explore the effects of the different curriculum models and the effects of curricular phase of the curriculum and gender on CR. In addition, the results of the summative knowledge-based exams were supplemented by interviews with students and teachers.

1.6. LIMITATIONS AND DELIMITATIONS

It was impractical to make comparisons before and after the implementation of the new curriculum, a process that would have taken more than 10 years to complete. This researcher, therefore, pursued a philosophy and design that was essentially descriptive and associative rather than rigorously comparative. The researcher generated significant volumes of data, particularly during the quantitative portion of the study. Quantitative data included information from a variety of students, different numbers of students, different summative knowledge exam papers, and different components of CR marks in each cohort. The researcher, therefore, conducted an independent sample t-test comparing the group means instead of conducting a pairwise analysis of the difference of scores. The total raw scores reflected the weight of the correct answers.

The effectiveness of the curriculum could not be measured fully in this study. Not all variables associated with the implementation of the CR curriculum could be

identified, controlled, and measured in the dynamically developing curriculum over the time period studied. However, the effects of CCSs were a small part of the CR curriculum that could be monitored. Only the relationship between participating CCSs and CR marks was measured as part of this quantitative study. Many other factors may also have affected these findings, including students' general level of diligence.

1.7. SIGNIFICANCE OF THE STUDY

Improving the critical thinking and CR skills of medical practitioners is important for ensuring that they deliver high-quality healthcare services in practice (Dale & Dale, 2017). This study provided an outline for the research design, methodology, and analysis of curriculum designs centred on the development, implementation and evaluation of a CR curriculum among UG medical students. The learning needs analysis portion of this study also served to provide guidance for how educators and school administrators can support the needs of their students in regard to learning about CR and the supplementary skills associated with it.

The findings of this study will help healthcare educators identify the skills needed for clinical teachers when educating the formerly informally taught concept of CR and provide information about the competencies and skills that were found to be useful when providing CR instruction to UG students. The results of this study can also be used to evolve theoretical considerations in the implementation of CR early in the education process and maybe helpful in standardising the assessment of the competencies of the curricula and for the feedbacking process among educators (Orban et al., 2017).

1.8. SUMMARY

This chapter highlighted relevant literature around CR and its pedagogy to provide a background to the current study. This study addressed the lack of

developmental studies geared toward understanding CR curriculum development at the UG level. With this study, the researcher aimed to evaluate the process of integrating CR in the UG curriculum of UoN's School of Medicine. Furthermore, this study aimed to evaluate the effectiveness of the new curriculum in enhancing the CR skills of the students and the CR teaching skills of the clinical teachers. The researcher also included the research questions guiding these goals and the conceptual framework of this study in this chapter. The chapter provided a brief overview of the nature of the study and the limitations and delimitations of the study are also explained. Finally, the researcher presented the significance of the study.

In Chapter 2, the researcher provides a necessary review of the existing literature in order to provide a background to the definition of CR and its nature. The review includes studies focused on the implications of the nature of CR and its pedagogy, acquisition, development, and assessment. The chapter also includes a review of the literature around CR curriculum and training. In Chapter 3, the researcher details the methodology for the study, providing a context for the methodology chosen by explaining the development of the CR curriculum for the UG medical degree of UoN, with particular focus on the teaching and assessment resources of the curriculum. The researcher also explains in detail the mixed methods approach employed for this study, outlining the qualitative analysis of the students' and clinical teachers' perspectives and the quantitative analysis of the summative exams through CP 1 and CP 3. In Chapter 4, the researcher provides a summary of the quantitative and qualitative results. In Chapter 5, the researcher discusses the findings and conclusions.

CHAPTER 2 REVIEW OF RELATED LITERATURE

Despite the breadth of literature around CR as a skill, trait, and concept, few researchers have addressed the effectiveness of CR curricula implemented among future medical practitioners. This study focused primarily on the development of clinical reasoning curricula among undergraduate students at UoN. The review of the literature consists of three major sections, the first of which tackles studies engaged with topics of CR definitions, nature, and history and studies focused on theoretical concepts related to clinical reasoning. The second review section includes scholarship regarding CR curricula and role of knowledge, different learning approaches, and faculty training on the implementation of CR-focused curricula among students in the medical field. In the third review section, the researcher discussed UoN's clinical reasoning curricula through a review of the university's educational resources, thereby providing a background for the study's context.

2.1. CLINICAL REASONING

In this section, the researcher provides a necessary background context and a review of existing literature on CR. Included in this section is an overview of the definition of CR and the common elements associated with it. This section details CR's basic history, as well as the importance of clinical reasoning in medical practice. The theoretical models and concepts associated with CR as explored in the literature also are presented, along with studies involving the development of CR skills.

2.1.1. Definition and Elements of Clinical Reasoning

The term CR – or one of its multiple synonyms – always appear in the list of objectives stated by most medical schools, licensing organisations, and speciality societies (Higgs et al., 2008; Kassirer, Wong, & Kopelman, 2009; Norman, 2005; Patel, Arocha, & Zhang, 2004). However, understanding, describing, and formulating

an appropriate definition for CR is a rather complex, multi-faceted process (Neufeld et al., 1981; Pelaccia, Tardif, Triby, & Charlin, 2011). For medical students, CR has a wider scope (Murphy, 2017; Seif et al., 2014). It is not an easy task to provide a clear scientific definition of mental terms such as thinking, reasoning, or judgment that are part of everyday language (Custers, 2018). This is equally true for CR (Norman, 2005). Though definitions and descriptions of CR differ, scholars typically converge on the idea that CR entails cognitive operations that allow clinicians to observe, collect and analyse information, resulting in decisions and actions that consider patients' specific circumstances and preferences (Durning & Artino, 2011; Eva, Hatala, Leblanc, & Brooks, 2007).

In a systematic review, Da Silva et al (2015) stated that the definitions of CR are varied and often lack a necessary consensus, but that some components are commonplace among various studies. CR is commonly defined as a thinking process, which is the systematic transformation of the mental representations of knowledge in a way that characterizes the possible or actual states of the world for some goal or purpose (Holyoak & Morrison, 2012). CR is also characterized to be present in all stages of the clinical cycle, from the selection of information to the treatment or prognosis phase. CR always leads to context-specific actions or decisions about patient care and involves interplay with the various factors associated with the situation of the patient and the patient himself/herself (Da Silva et al, 2015). CR, therefore, is a fundamental part of healthcare competency (Durning et al., 2011). Da Silva et al (2015) added, however, that CR is susceptible to heuristics and bias.

CR is a type of thinking process through which a doctor manifests his/her ability to make clinical decisions based on the clinical information that is made available to him and his/her experiences in the profession. The clinical information

can include the patient's history, results of tests/investigations, and observations made during physical examination. However, this process can often include elements of clinical uncertainty and doubt (GMC, 2009). Similarly, CR has been defined as the ability to mobilize, manage, and interpret knowledge and doubt within the clinical context (Kassirer et al., 2009). It has also been defined as the cognitive process of integrating information from a clinical case with the physician's knowledge to be used for diagnosis and management of a patient's problem (Konopasek et al., 2014; Turpin & Higgs, 2017; Vaughan-Graham & Cott, 2017).

CR is the range of strategies that clinicians use to generate, test, and verify diagnoses in order to assess the benefits and risks of tests and treatments and to judge the prognostic significance of the outcomes of these cognitive achievements (Raupach et al., 2016). These definitions encompass the notions that: (a) CR is a cognitive process (Olupeliyawa, 2017); (b) CR reflects the clinical cycle phases (history, diagnosing, testing, treatment and prognosis); and (c) CR highlights the sub-processes that take place during this process (specifically, generating hypotheses, testing, assessing and evaluating risk/benefits, and making judgments regarding outcomes). All these can be identified in scheme presented by Bowen (2006), as presented in Figure 1 below.

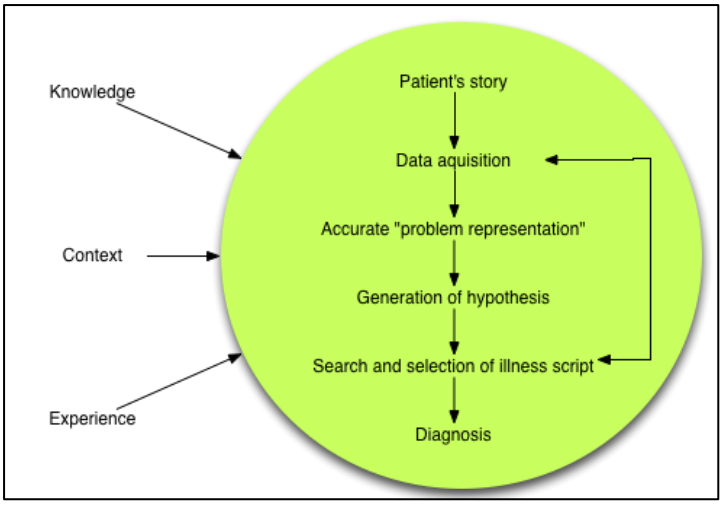


Figure 2.1. Bowen's model (Bowen, 2006).

These definitions only focus on the process of CR, stressing the cognitive process taking place in a physician's mind. Cooper et al. (2016) emphasised that CR also involves the set of reasoning strategies that permit healthcare professionals to combine and synthesise diverse data into one or more diagnostic hypotheses, make complex trade-offs between benefits and risks of test and treatments, and formulate plans for patient management. CR also involves several elements as seen in Figure 2.2 (Cooper et al., 2016).

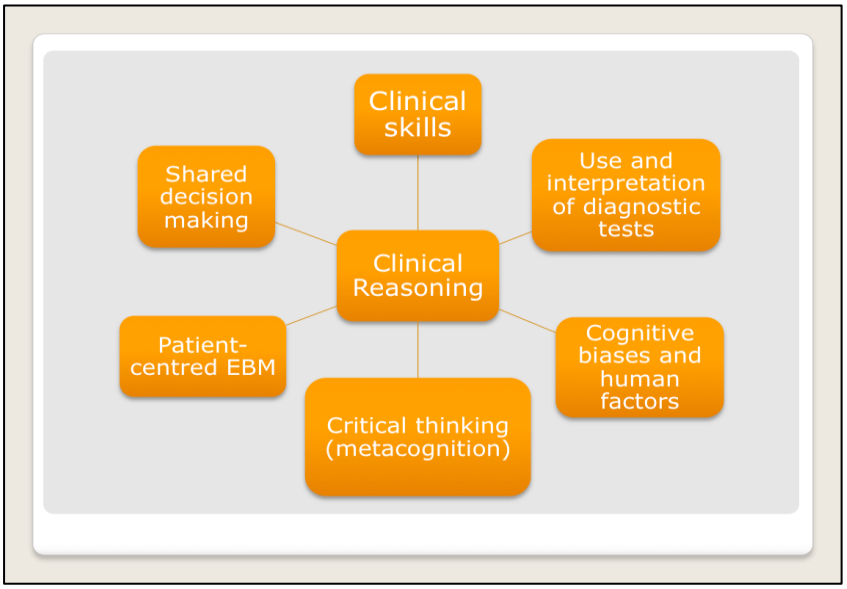


Figure 2.2. The elements involved in CR (Cooper et al., 2016).

Multiple definitions for CR appear in the literature, with a spectrum of complexity associated with these definitions. One of the extensively quoted definitions is by Higgs et al. (2008), who described CR 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 CR 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. (p. 4)

Higgs et al. (2008) stated that CR should be treated as a lived phenomenon and as an experience, rather than simply being described as a process. The researchers stated that it constituted core dimensions of knowledge, cognition, and metacognition along with other additional components (see Figure 2.3).

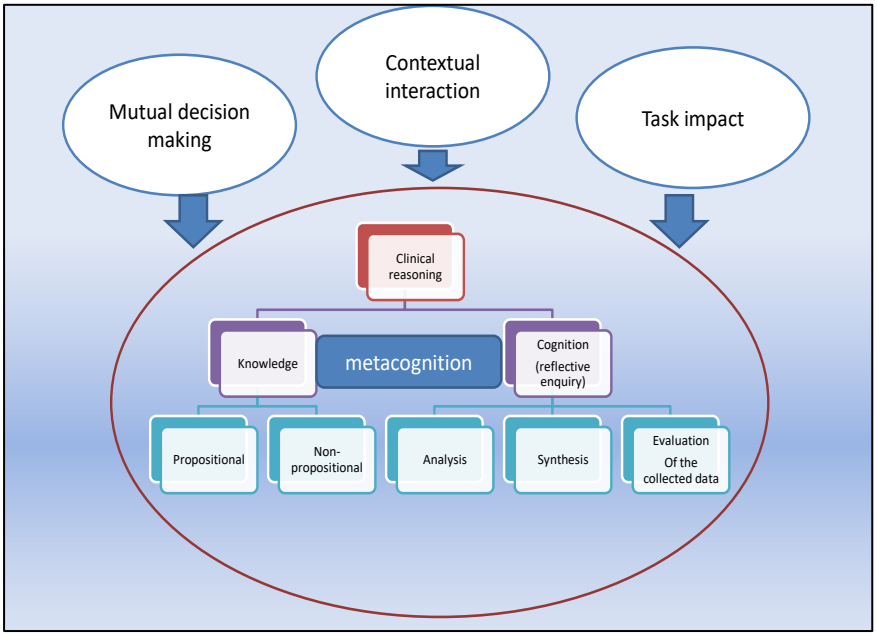


Figure 2.3. The components of CR as suggested by Higgs et al. (2008).

The first core dimension is knowledge. Propositional knowledge comes from theory and research whereas non-propositional knowledge comes from professional and personal experience. The second core dimension is cognition or reflective enquiry. Metacognition or reflective self-awareness can serve as a bridge between knowledge and cognition. Metacognition is the process of thinking about thinking itself and is key in CR. It is also defined as a voluntary, self-monitoring, and conscious act of thinking (Asadi, Volos, Marefat, & Bose, 2016). CR has additional dimensions pertaining to its interaction with the environment and human factors (Higgs et al., 2008).

CR, medical problem-solving, diagnostic reasoning, and decision-making are different terms used to describe the process of how clinicians make decisions. However, some researchers make distinctions among these terms. Clinical decision-making can refer to the process that mediates between the reasoning and actual action and decision making is considered as the product and/or the process of CR (Richard et al., 2017). Although CR is an important component of competent medical practice, there is little agreement regarding the nature and definition of CR. Providing a definition that best reflects this skill, process or phenomenon is difficult because of the complexity attached to it. This diversity may be problematic for the implementation of CR curriculum and could lead to confusion.

2.1.2. Brief History of Clinical Reasoning

During the general problem-solving era, researchers had an objectivist perspective to CR and problem-solving in general. Objectivists concluded that only one set of truths could be discovered. In the context of clinical reasoning, CR skills may be treated as a trait, with skill levels that must be constant and independent of factors such as physical location (Durning, Artino, Schuwirth, & Al, 2013). During

this period, expertise in CR meant that a person was an expert in problem-solving, which can be measured as a distinct skill that separated experts from novices (Bowen & Ten Cate, 2018). CR was believed to be a type of general problem-solving skill.

However, the constructivist epistemology of CR posited that CR is a state rather than a trait. The constructivist view of CR defined it as a result of continuous interactions between the clinician and many factors; thus, skills varied in different conditions. This constructivist view posited that CR goes beyond knowledge content, with the context, the clinician's experiences, and the specific features of patients causing variations in CR performance.

Researchers then began to focus on the processes of acquiring and organizing CR knowledge rather than focusing on CR as a skill or trait (Cheng et al., 2015). Elstein, Shulman, and Sprafka (1978) performed a comprehensive study of CR by using simulated patients and cases. They found that there was no difference in the processes or strategies used by expert clinicians and students, reporting that both quickly came up with one or more diagnostic hypotheses that guided the search for further information. However, when the experts produced a diagnosis, their rationales were more accurate because they knew more as a result of clinical experience, and probably organised their knowledge differently as a consequence. They also found that success in one problem was a poor predictor of success in another. The performance of even experienced physicians varied markedly from case to case within their own specialties. Elstein et al. (1978), therefore, concluded that information and experience were two of the most important determinants of competence. Problem-solving skills without a rich supply of facts were insufficient for diagnostic acumen.

Further studies on CR showed the emergence of social cognitive theories as applied to the context-specificity of CR. Situativity, in particular, argued that

cognition or thinking were situated in the specifics of a given encounter (Durning et al., 2011). In this view, encounters could be broken down into several factors such as the patient, the physician, the other health care members, and the environment or system. This perspective of CR supported the constructivist epistemology of CR.

2.1.3. Theories and Models Underlying Clinical Reasoning

There are diverse theoretical concepts that underlie the current understanding of the CR process. The main epistemological views of CR are typically divided into objectivist and constructivist theories, as discussed in the previous section (see Figure 2.4). The different theories are discussed briefly in this section.

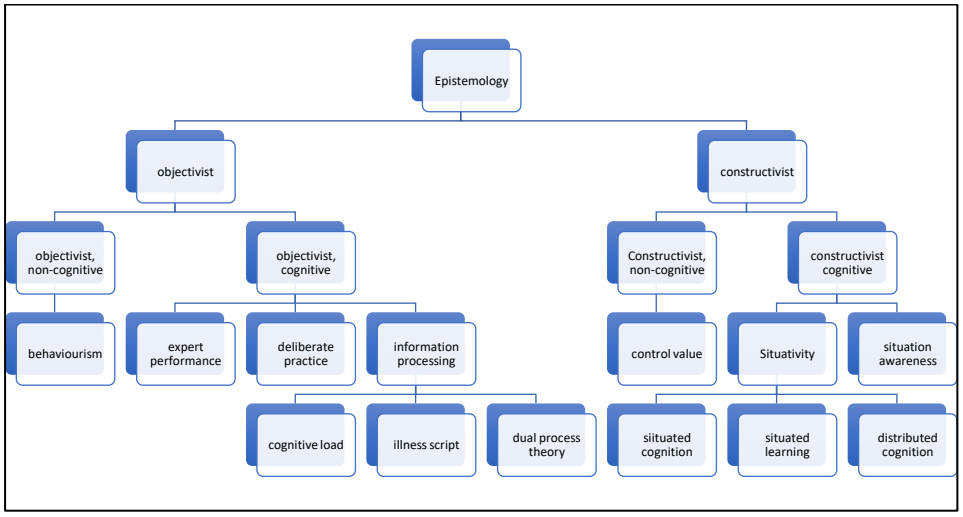


Figure 2.4. The related theories that shape and affect our understanding of clinical reasoning.

Objective theories can be cognitive or non-cognitive. The objective non-cognitive or behaviourist perspective of CR incorporates the things that can be seen in clinical settings, omitting clinicians' thoughts and emotions. However, there is a spectrum in this theory, with the view just described being that of the strict behaviourist. In addition, strict behaviourists believe that CR can be learned through behaviour modification following the receipt of rewards or punishments (Nafea, 2015). Although this theory is not a major guiding force for learning in medical education, some of its components remain in situations where the assessment focuses on measuring outcomes (behaviour) rather than on cognitive processes as measured in competency-based assessment.

Objective cognitive theories of CR posit that expert CR performance requires a rich, content-specific knowledge base that monitors and controls the cognitive process to perform a limited set of activities efficiently and effectively (Feltovich, Prietula, & Ericsson, 2006). Content-specific knowledge is also important to CR but is not sufficient. Deliberate practice is needed to achieve expert performance. The theory of deliberate performance argues that expert performance in CR emerges when one engages with the content with a substantial amount of effort and under the direction of a coach who provides substantive feedback on the learner's performance. Ericsson (1990) said that it takes 10,000 hours of deliberate practice to become an expert in almost anything (Ericsson, Charness, Feltovich, & Hoffman, 2006).

Other objective cognitive theories – such as information processing theory and cognitive load theory – also inform our understanding of CR. Most definitions of CR follow the information processing theory, which suggests that as more knowledge is organized to resemble the orderly modelling of a computer program, more efficient CR and diagnostic success results (Bordage, 1994; Newell & Simon, 1972). This is in

line with cognitive load theory, which posits that the limited human cognitive architecture affects a person's ability to cluster information into special patterns (Norman, 2005). The ability to do this can create differences between experts and novices (Miller, 1956). Other theories, including schema and illness script theory and dual process theory, also frame the concept of CR. Schema pertains to the larger, well-organised, and well-defined clusters of memory. Ill illness script pertains to a specific type of schema or mental representation of the clinical symptoms and findings that can be observed with a given disease. Scripts are dynamic and are continually refined through one's clinical experience. The development of illness scripts is a suggested step toward developing CR among medical students (Charlin, Tardif, & Boshuizen, 2000). Dual process theory is also applicable to CR through a combination of non-analytic reasoning or fast thinking. Dual process theory refers to pattern recognition and heuristics or cognitive shortcuts and analytic reasoning or slow thinking, which involves deductive reasoning, inductive reasoning, categorical reasoning, and probabilistic reasoning (Kahneman, 2011; Norman, 2005). Dual process theory contends that both thinking processes are used in CR in varying proportions based on the specific nature of the task (Hughes & Nimmo, 2016).

One issue of these individual objective theories of clinical reasoning is the lack of applicability of the phenomenon of context specificity (Eva, Neville, & Norman, 1998). Context specificity has led to the emergence of various theories that emphasise not only the clinician and his/her skills but also how he/she interacts with the patients and their environments.

Constructivist non-cognitive theories on CR include theories on motivation and emotion, including control value theory (Artino, La Rochelle, & Durning, 2010). In the context of CR, control value theory posits that one will not engage in effortful

practice to achieve expertise without significant motivation. There are both activating emotions and inhibiting emotions. Not all negative emotions inhibit learning. In fact, small amounts of negative emotions can actually improve performance as long as the learner is not overwhelmed (Trowbridge, Rencic, & Durning, 2015). On the other hand, constructivist cognitive theories on CR – situativity, for example – posit that the participants, the environment, and their interactions influence CR (Durning et al., 2011). Situativity theorists view CR as a non-linear process involving varying theories with many elements that interact.

Situated cognition proponents view CR or other cognitive processes as being located in situated experience. In order to understand reasoning, we need to study the characteristics of experience and situations associated with it. In this case, environmental variations and interaction are seen as variables (true variance) rather than as the sources of noise or error that other previously discussed theories would categorize them as (Durning et al., 2011). Situated learning stresses participation in an activity and identify formation as learning versus acquisition of "static" facts. Identity is formed through legitimate peripheral participation such as participating in the community with gradual increase in responsibilities and influence (Trowbridge et al., 2015). Distributed cognition is a third theoretical perspective that relates to group thinking, with proponents seeing answers as not being situated in the head of any one individual and concluding that certain activities require interactions with several participants to be successful (Trowbridge et al., 2015).

Different models and frameworks have been put forward by different research groups and authors. These models can be allocated into two main groups, the first of which is concerned with the cognitive process, or objectivist view. The second group

of models reflects the view of CR as an interactive process, or constructive view (Higgs et al., 2008), as in Figure 2.5.

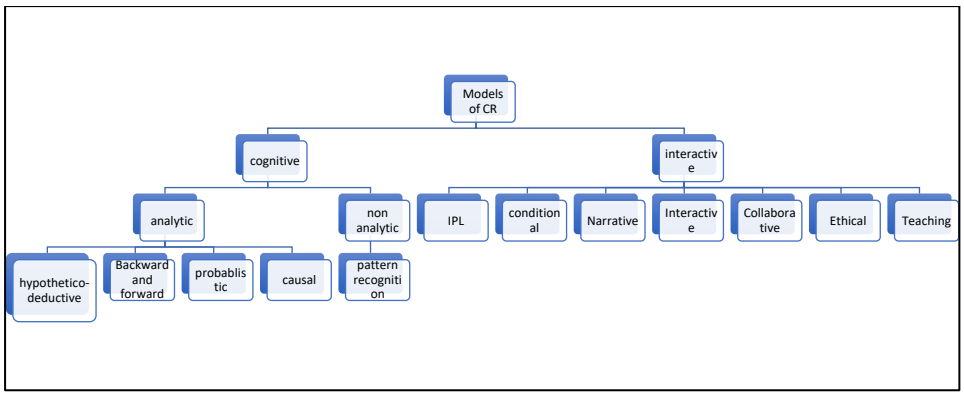


Figure 2.5. Models of CR.

CR has been modelled as a cognitive process based on analytic and non-analytic reasoning models. Analytic reasoning processes include hypothetic-deductive CR, first suggested by Elstein and Schwartz (2002). The theory models CR as the process of posting the differential diagnoses and then assessing whether that individual diagnosis adequately explains the observed symptoms, findings, and any obtained test results. If it does, then the diagnosis is confirmed. However, it is not possible to determine whether every competing hypothesis has been considered and excluded (Trowbridge et al., 2015). In such a model, the hypotheses would be knowledge driven, and would be the centre of an iterative process of hypothesis-testing-hypothesis (Elstein et al., 2002). Diagnosis would be a guided search of data (Elstein et al., 2002) to confirm or discredit previous hypotheses that would encompass four stages: “cues acquisition, hypothesis generation, cue interpretation, and hypothesis evaluation” (Patel, Arocha, & Zhang, 2005). Experts would differ from novices not only in the number of hypotheses offered but also by the quality of their hypotheses (Patel et al., 2005).

However, in a study conducted with expert cardiologists, Patel et al. (2005) concluded that clinicians who correctly diagnosed a disease did not use the typical hypothetic-deductive reasoning, as their searches were not based on lists of hypotheses. Rather, clinicians with better diagnostic performance were engaging in data-driven reasoning, in that they would weigh all the evidence, seek patterns until they had all the data from the patient, and only then form a hypothesis that would provide coherent explanations for all the data. In other words, forward reasoning or inductive reasoning is the thinking approach that starts with symptoms to develop a hypothesis that adequately explains them. In other words, a clinician uses clinical findings, risk factors, natural history, and basic science knowledge to develop a hypothesis that adequately explains those symptoms (Trowbridge et al., 2015). In contrast, hypothetic-deductive reasoning would be designated as backwards reasoning since it moves from the hypothesis to the data (Patel et al., 2005). Patel et al. (2005) and Patel and Kaufman (1990), however, recognised that forward reasoning is not used in all circumstances, and suggested a reconciliation hypothesis. The researchers suggested that in more difficult cases or in cases out of the normal range, expert reasoning breaks down, shifting from forward reasoning into a backwards reasoning mode (Patel, Evans, & Kaufman,1990); (Patel & Kaufman, 2000).

Probabilistic reasoning is also used as a key model for CR. Probabilistic models suggest that clinicians use analytical approaches to solve clinical cases (Oaksford, 2007). In this process, a clinician uses mathematical formulae to calculate the probability of a certain diagnosis based on general information about the prevalence of the condition, results of the patient's tests, and the sensitivity and specificity of the test performed. This model focuses more on how clinicians choose between hypotheses rather than on how those hypotheses are formulated (Oaksford,

2007). Causal reasoning is another aspect of the diagnostic process based on the cause-and-effect relationships (Kassirer et al., 2009). The clinician uses basic science concepts to confirm or refute a hypothesis generated using other reasoning strategies. It is not particularly helpful by itself in producing a hypothesis (Hughes et al., 2016). Causal reasoning also relies on common sense notions of causality (Kuipers, 1984; Susser, 1973).

Non-analytic reasoning or pattern recognition is also used to model CR. Diagnostic thinking is based on the unconscious and rapid matching of a present problem to a previously encountered and similar problem (Norman, Brooks & Allen, 1989). Experts would accumulate large databases of cases. By recognising specific features in a problem, they would then be able to retrieve past cases that would match those same features and all information related to it from memory (Norman, Young, & Brooks, 2007). In their view, CR is not an analytical process, but rather a faster, more intuitive, and less conscious process (Norman et al., 1989). It allows the clinician to deal with larger amounts of information simultaneously (Evans, 2008). It is, at the moment, one of the best available explanations to expert CR (Norman, 2005). It is also rule-based, categorical, and deterministic reasoning. Intuitive reasoning is another form of pattern reasoning. Intuitive knowledge is associated with past experience of specific clinical cases or scripts. This can be used unconsciously during inductive reasoning.

Novices will struggle with pattern recognition because they do not have the necessary experience and knowledge to have compiled a database of standard responses (Norman, Barraclough, Dolovich, & Price, 2009; Patel et al., 2005), and experts acting outside their areas of expertise will similarly be unable to resort to this method. Experts use iterative reasoning to solve clinical problems, which means they

are able to change from a non-analytic reasoning to a hypothetic-deductive reasoning when cases present higher degree of difficulty (Norman et al., 2007). According to this perspective, there is no dichotomy between analytic and non-analytic reasoning when solving clinical cases. There is a continuum between both systems that shifts according to the context, situation and case (Offredy, Kendall, & Goodman., 2008).

2.1.4. Factors Affecting Clinical Reasoning

There are many factors affecting the development of CR skills. Higgs et al. (2008) also described CR as "a context-dependent way of thinking." The context can include the task attributes, patient attributes, external context, or environmental attributes, as well as attributes related to the decision maker (Nafea 2015; Smith, Higgs, & Ellis, 2008). The nature of the task has an impact on the decision-making process. Acute cases, in which the patient is in severe pain, require healthcare professionals to take prompt action to deal with this pain rather than spending time searching for possible causes. As described earlier, clinicians usually approach clinical cases differently based on the complexity. For the familiar cases, they usually follow the non-analytics reasoning and if the task involves unusual clinical cases, analytic reasoning will dominate the process. However, there is always a possibility for using mixed strategies when making clinical decisions. In case the decision involves identifying high risks of life-threatening conditions, clinicians usually carry out extensive investigations in a strategy of ruling out the worst-case scenario. However, frequent reliance on this strategy in all cases may lead to over-investigation of patients and extensive use of resources, reducing the efficiency of decision making (Geary & Kennedy, 2010). For example, the diagnosis of a simple pneumonia does not need the same degree of certainty as a diagnosis of leukaemia before treatment is

commenced. In conclusion, the assessment of the level of risk together with avoidance of risk is considered to be factors affecting clinical decisions (Stempsey, 2009).

In addition to the nature of the task, a patient's attributes also play a role in the CR process. Traditionally, the physician is responsible for making the best decision on behalf of patients. However, with the current shift toward a more patient-centred approach in health care, patients get more involved in the decision-making process (Smith et al., 2008) as mentioned earlier in narrative reasoning, interactive reasoning, and collaborative reasoning. Frost, Cook, Heyland, and Fowler (2011) performed a systematic review to determine which factors are known to influence end-of-life decision-making among patients and healthcare providers and concluded that patients and clinicians may approach end-of-life discussions with different expectations and preferences, influenced by religion, race, culture, and geography. Patients' preferences are influenced by demographic variables, with younger, better-educated patients and women being quite consistently found to prefer a more active role in decision making; their experience of illness and medical care; their diagnosis and health status; the type of decision they need to make; the amount of knowledge they have acquired about their condition; their attitude toward involvement; and the interactions and relationships they experience with health professionals. Their preferences are likely to develop over time as they gain experience and may change at different stages of their illness (Say, Murtagh, & Thomson 2006). Elizabeth, McKinley, Garrett, and Evans (1996) concluded that African-American (black) and white cancer patients make different end-of-life choices, even after adjusting for likely explanatory variables.

Different types of contextual factors may also affect the decision-making process. Recent work in CR has highlighted the concept that excellence in CR is a

state rather than a trait. CR abilities are situation specific, resting with a particular patient in a specific setting with specific resources and interactions with both the patient and the environment. Contexts of the clinical problems are different in different health care divisions. Much research regarding the effect of context on the problem-solving process has been conducted (Shafaroodi, Kamali, & Parvizy, 2014; Smith, Higgs, & Ellis, 2007; Wainwright, Shepard, Harman, & Stephens, 2011). The context of clinical problems 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. In some cases, especially when a novice was uncertain about the best decision to choose, they referred to other individuals. This suggests the importance of social factors and communication skills with colleagues in the clinical environment in deciding. Patel, Kaufman, and Magder (1996) reported that decision-making could be influenced by the hierarchy and social structure of the organisation.

In addition to these, the attributes of the decision-maker can also influence the CR process. The results of Groves, O'rourke, Alexender (2003) 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) (Groves, O'rourke, Alexender (2003)). 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, V., Liaghatdar, M. & Adibi, P. 2012, Anderson, 2006, Staff, 2014, Shafaroodi, Kamali, & Parvizy, 2014, Da Silva, 2013).

It has been suggested that the stage of UG study can affect medical students' levels of CR skills (Nafea, 2015). Neufeld concluded in his study that the CR process remained relatively constant from UG to postgraduate level, with only the measure of content in the students' hypothesis correlating with both outcome and educational level. This implied that medical students' knowledge is developing but that the development of their CR skills remained relatively constant during this period (Neufeld et al., 1981). On the other hand, Groves, O'rourke, Alexender (2003) and Da Silva (2013) stated that CR skills develop throughout the successive progress of the students. Hmelo (1998), Koh , Khoo, Wong, & Koh (2008), and Norman and Schmidt (2000) also reported that the clinical phase of the curriculum had a strong impact on students' CR. Good clinical skills such as communication skills were also vital since the heart of CR is often the patient's history and physical examination. (Windish et al., 2005). It has also been suggested that communication skills training may improve students' CR ability because this training would aid in gathering more accurate information regarding both biomedical and psychosocial histories (Evans, Stanley, Mestrovic, & Rose, 1991). Critical thinking also could be considered as one of the most important factors affecting the development of CR skills, since it entails the examination of those structures or elements of thought implicit in all reasoning (Nafea, 2015). The importance of critical thinking for medical education has been reflected in the objectives of most schools since these are commonly directed toward educating students to be critical thinkers (Facione, Oxman-Michelli, & Weinstein, 1991). It was suggested that developing the skills for critical thinking could facilitate

the development of CR in medical students (Christensen, Jones, Higgs, & Edwards, 2008).

2.2. CLINICAL REASONING CURRICULUM

This section details the role of curriculum design in CR development as well as the general pedagogy of clinical reasoning. The role of the curriculum and the knowledge also appears in this section, along with the importance of reflective learning and a discussion of the importance of faculty training. In this chapter, the researcher also presents the means of CR assessment, concluding with an explanation of the drivers for curricular change and the importance of clinical reasoning for medical schools and the society at large.

2.2.1. The Pedagogy of Clinical Reasoning

Diagnostic errors result in an estimated 40,000 to 80,000 deaths annually in the United States alone (Leape, Berwick, & Bates, 2002; Newman-Toker & Pronvost, 2009). In fact, claim data showed that pay-outs for diagnostic errors exceeds pay-outs for surgical and medical errors (Studdert et al., 2006; Weeks, Foster, Wallace, & Stalhandske, 2001). Diagnostic errors often have multiple causes, with many originating in both systems and cognitive errors. Until recently, medical education has focused on systems-based errors as the most significant cause of medical errors (Croskerry, 2003). Although such systems-based errors are common, most errors also contain faulty cognition on the clinician. So medical educators and patient safety practitioners have placed a renewed focus on diagnostic/cognitive errors (Graber et al., 2012; Myers & VonFeldt, 2009; Newman-Toker et al., 2009; Wachter, 2010). The cognitive errors can occur at any step in the diagnostic process including inadequate knowledge, poor data collection or organization, faulty synthesis, biased thinking, and influences from the external environment and system (Reilly, 2015).

This establishes the importance of teaching CR in medicine. It is reflected in Marcum's (2012) view this way: "If medical students are not taught how they should reason by setting explicit conditions, then they may develop poor reasoning skills implicitly" (p. 960). Given the centrality of effective CR to high-quality patient care and the importance of being knowledgeable about diagnostic errors, it is incumbent upon training program to ensure its graduate are competent at CR (Kogan & Hlomboe, 2015). It is a core ability to be mastered during training and refined throughout career. 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 judgment. Although this fact is well known, CR has been rarely taught in medical schools in formal teaching formats (Round, 1999, Felix et al., 2015). Additionally, there is no clear consensus on how CR might best be taught or how it should be assessed (Durning et al., 2013). Dalton, Gee, and Levett-Jones (2015) added that critical thinking should also be reflected in the medical education curriculum because it helps practitioners make decisions and draw conclusions on the basis of data regarding a particular medical case. However, there are many challenges and barriers to teaching CR. Ledford and Nixon (2015) summarised these barriers in Table 2.1 below.

Table 2.1.
Challenges and Barriers to Teaching CR (Ledford & Nixon, 2015)

Factor types	Barriers
Content factors	Diagnostic reasoning is a complex ability with multiple components. CR is often tacit, inferred from decisions or actions
Environmental factors	The 2 + 2 student curriculum (i.e.,2 preclinical years followed by 2 clinical years) may hinder knowledge transfer to the clinical context Opportunities for CR practice are limited by the randomness of exposures to different diseases types. Practice of diagnostic reasoning is difficult when patients are already worked-up" A lack of longitudinal follow-up with patients limits natural feedback about reasoning process Clinical care can be fast paced and associated with frequent transitions of care (handoffs)
Teacher or expert physician factors	Lack of awareness of one's own reasoning processes Limited knowledge of general CR principles Limited time to directly observe and assess learners' clinical skills Difficulty providing specific, meaningful feedback on CR

Achieving excellence in CR is context-specific, making it difficult to ascertain the overall CR skills of an individual. Hendricson et al. (2006) also said it is still a matter of conjecture as to the best practice strategies for helping students to acquire the skills needed for CR. Existing literature revealed considerable debate regarding the best educational strategies and philosophies for enhancing (Ryan & Higgs, 2008). But the understanding of elements of CR and the theoretical concepts of CR can inform how to teach. One of the most consensual conclusions of research into CR is its close dependency on the knowledge domain (Norman, 2005). Building a solid base of medical knowledge along with developing the necessary skills for medical practice is a key element allowing the development of CR (Boshuizen & Schmidt, 1992;

Schmidt, Norman, & Boshuizen, 1990). It is important to bear in mind that medical knowledge now has a short shelf-life, making it equally important to guarantee that the students have the necessary skills to keep their knowledge updated (Boshuizen, 2003).

Beyond knowledge and knowledge organization, students need to become familiar with both non-analytic and analytic reasoning (dual-processing) so that they can be as flexible as required for given diagnostic problems (Ark, Brooks, & Eva, 2007). The most common form of non-analytic reasoning is pattern recognition. To support development of pattern recognition, students should store knowledge such as disease prototypes that are organized as illness scripts (Schmidt & Rikers, 2007). Encouraging students to compare and contrast the diagnostic possibilities in relation to the obtained data from specific patients could enhance the development of illness scripts (Bowen, 2006). 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, Sullivan, & Fleming, 2013). Teaching analytic reasoning is also important not only because it is a precursor to non-analytic thinking but also because sequentially combining non-analytic with analytic reasoning may reduce clinical errors in complex cases (Mamede et al., 2010). Educational interventions should stimulate the use, alone and combined, of both analytic and non-analytic reasoning (Croskerry, 2009; Norman et al., 2009).

2.2.2. Role of Curricula in Clinical Reasoning Development

Medical education does not just involve learning a subject and is more than following a course of study. It also is induction and guidance into the medical profession. In the Oxford dictionary, curriculum is defined as the subjects comprising

a course of study in a school or college. Grant (2013) stated that a curriculum is an ideological statement that expresses beliefs, values, and aspirations that align the institutions with key groups like healthcare services, professions, and communities. Curriculum is a freely available document that lays out the framework for how students will achieve learning objectives through competencies in terms of attitudes, skills, and knowledge gained through a learning program within a designated timeframe (Dennick, 2010).

The curriculum structure has the capacity to influence the learning and cognitive processes of students. For example, it has been suggested that medical students store knowledge in the same way that the information was taught. For instance, if knowledge is taught according to organ systems, knowledge will also be stored in categories of organ systems, with recall of information triggered by prompts related to organ systems. This, in turn, may delay the problem-solving abilities of the students, as patients usually present by combinations of symptoms related to multiple organ systems (Nafea, 2015). During the clinical phase, students usually form connections between biomedical science and clinical cases, making short cuts and faster retrieval of knowledge (Bowen, 2006).

Patel, Groen, and Norman (1991) compared the results of a traditional medical curriculum with that of a PBL curriculum. Students in the PBL curriculum revealed more backward-directed hypothetic-deductive reasoning whereas students in the traditional curriculum revealed a more forward-directed pattern of reasoning. It was found that the PBL curriculum may facilitate the development of inductive reasoning in students. PBL students also produced higher quality explanations using biomedical information, which can be a sign of a better ability to integrate new knowledge (Patel et al., 1991). Additionally, Norman and Schmidt's (1992) study of PBL also

concluded that over time, PBL seems to increase knowledge retention and enhances both transfer of knowledge to new problems and the integration of basic science into clinical problems. Furthermore, PBL also seems to increase motivation, interest, and self-directed learning skills (Norman et al., 1992). These results were also supported by Hmelo (1998). The results clearly favoured the PBL curriculum as fostering the students' ability to provide more integrated and complex explanations and their ability to transfer reasoning strategies across learning environments (Hmelo, 1998). Some literature stated that PBL has a positive influence on CR (Prosser & Sze, 2014; Choi, Lindquist, & Song, 2014; Martyn, Terwijn, Kek, & Huijser, 2014; Dolmans et al., 2015; Savery, 2015).

In contrast, Norman et al. (1992) found evidence that PBL did not improve students' CR. The reason is that such skill is controversial and has been discredited in favour of domain and content-specific problem-solving skills. The PBL students committed errors of scientific fact and generated less coherent explanations than students on a conventional medical curriculum (Patel et al., 1993). Some studies supported those findings (Boshuizen, 2003; Gross et al., 2016; Kaufman, Yoskowitz, & Al, 2008; Nafea, 2015; Norman et al., 2000; Schmidt et al., 1996). Some published studies revealed that PBL curriculum had a small effect in enhancing the level of CR and diagnostic ability among students (Colliver, 2000; Jolly, 2006; Pardamean, 2012). Albanese (2000) stated 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 indicates the success of curriculum intervention. Norman et al. (2000) produced a paper that challenged Colliver's (2000) findings regarding the marginal effect of PBL in fostering knowledge base and clinical performance. They suggested using a systematic research programme and test

the effectiveness of educational intervention in realistic settings accompanied by considerations of all possible variables and interactions. Some studies have found that both critical thinking or reasoning and problem-solving skills were only weakly associated with the PBL curriculum (Koh et al., 2008). Similar results were found by Mamede, Schmidt, and Geoffrey (2006). According to them, this meant that the research agenda should analyse particular aspects of PBL on defined variables rather than only focusing on the curriculum as a whole since such studies would contribute to a better understanding of the complex interactions taking place in PBL.

Following this view, Arts, Gijselaers, Wim, and Segers (2006) conducted an experimental study with an experimental group versus control group to compare a redefined PBL curriculum. Their conclusions supported the idea that PBL fosters reasoning and problem-solving. The PBL students outperformed the control students in various aspects of expertise when analysing a problem: more extensive use of domain-specific concepts and inferences, more inductive reasoning, and both diagnoses and solutions of higher quality. These results also indicate that students in the PBL group use strategies closer to the non-analytical model of reasoning and/or forward reasoning (Arts et al., 2006). Hoffman et al. (2006) used students' scores on the United States Medical Licensing Examination to evaluate the effectiveness of the implementation of a PBL curriculum. Their results showed a significant positive effect of PBL curriculum for both knowledge application-focused and clinical problem-solving-focused aspects. Their conclusion was that the PBL curriculum better prepared students for residency and clinical practice (Hoffman et al., 2006).

Brauer and Ferguson (2015) argued that integrated curriculum is more beneficial for the teachers and students as it allows them to integrate a variety of concepts, which have more relevance to the practical life of students. One of the

studies, which compared the diagnostic accuracy of medical students from the three different types of curricula, 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). Da Silva (2013) studied these aspects in a traditional medical school, another school with a different cultural environment and delivering a more contemporary systems-based integrated curriculum, and a third school from a similar cultural environment, which has adopted the problem-based learning strategy. It has been found that although there are significant differences in CR 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 toward graduation there is no differences in reasoning ability based on the type of UG curriculum (Da Silva, 2013; Groves, O'rourke, & Alexander, 2003). The results of the quantitative study by Nafea (2015) showed that the type of UG curriculum had a minimal effect on the marks obtained by the final year students coming from different dental schools using an online CR test. On the other hand, the results of the qualitative study, 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.

Although, multiple studies have been conducted to examine the effect of the curriculum on CR, its role in enhancing the development of CR skills in medical students is still not well understood (Patel, Evans, & Groen, 1989; Patel et al., 1991;

Sefton, Gordon, & Field, 2008; Schmidt et al., 1996; Goss, Reid, Dodds, & McColl, 2011). Most of the results were contradictory and there was no consensus on a single best curriculum model to enhance CR.

2.2.3. Role of Knowledge Organization and Information Processing

Knowledge, in particular, is crucial to the development of CR. Biomedical knowledge, which involves basic science subjects including biochemistry, anatomy, and physiology as well as clinical knowledge, which is concerned with disease entities and associated findings are important during the CR process (Kaufman et al., 2008). The relationship between these two knowledge groups has been studied and it has been hypothesised that these two types of knowledge are stored separately in the minds of medical practitioners and they use biomedical knowledge only if pattern recognition is not possible. However, it has also been hypothesised that medical expertise is an incrementally developing process in which the knowledge base is changing regularly in a process known as knowledge encapsulation. It has been argued that activation of biomedical science knowledge is also a feature of experts' CR. Experts use this knowledge instantly when they need it (Linsenmeyer et al., 2017). Although both hypotheses explained the relationship between biomedical and clinical knowledge differently, both have stressed the importance of biomedical knowledge in gaining expertise in CR. A recent study has suggested that there is a negative relationship between these two types of knowledge on medical students because of their inappropriate separation in the traditional curriculum (Schauber, Hecht, Nnouns, & Dettmer, 2013).

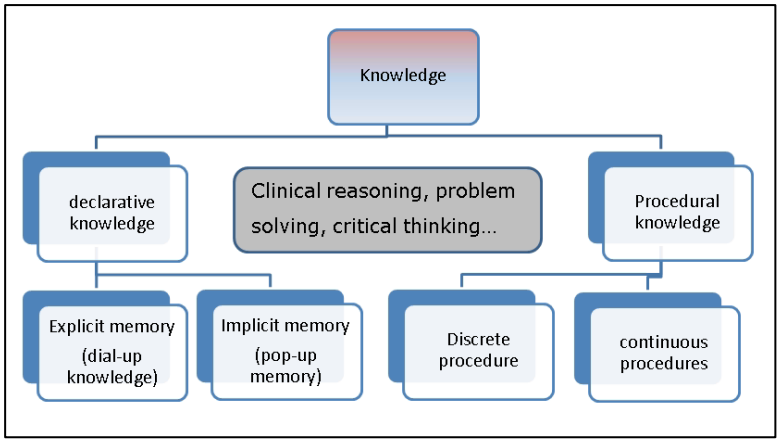


Figure 2.6. The structure of knowledge.

There are different types of knowledge that affect CR development (see Figure 2.6): declarative knowledge, procedural knowledge, and the area between these two zones involving critical thinking and decision-making skills. Declarative knowledge focuses on memory components, which comprise factual information such as names, places, and associated emotions as well as memories retrieved through stimuli or pattern recognitions. Procedural knowledge focuses on knowledge from discrete performance and continuous action performance. Discrete procedure is a well-defined sequential action with predictable outcomes and has well-known steps to be performed, whereas, continuous procedures involve a series of actions and needs to be coordinated with continuous monitoring of the environment, such as driving a car (Hendricson et al., 2006).

Knowledge is then stored and organized in different ways, based on a person's limitations in terms of cognitive load (Ratcliffe & Durning, 2015). Prototype theory provides an explanation for expert diagnostic skills (Bordage, 2007). The basic assumption was that the difference between experts and non-experts depended on the efficiency of their organisation of knowledge, making retrieval processes less demanding cognitively, faster, and less prone to errors (Bordage 2007). However, Ericsson (2007) and Norman (2005) said that prototype theory was not clear enough

to explain the relationship between prototypes and diagnostic ability. Even Bordage (2007) proposed that this organisation must be a product of semantic qualifiers, which are abstract descriptors according to which concepts are classified, stored and integrated with previous networks.

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 learned and a knowledge network is developed and refined to produce better connections. CR in this stage is characterised by the detailed elaboration of knowledge with specific lines of reasoning (Boshuizen & Schmidt, 2008). The knowledge is then encapsulated. Encapsulation of biomedical knowledge allows students to progress to the next step toward the development of CR expertise. They mainly focus on the clinical information of the clinical cases, formulating hypotheses or diagnoses (Schmidt & Boshuizen, 1993).

2.2.4. Role of Experiential and Reflective Learning

Pattern recognition is also learned through the process. It is defined as a process developed with the transition from a rational knowledge base, acquired via educational experiences, to a non-analytic ability to recognise and handle familiar situations (Van der Vleuten & Newble, 1995). Despite the importance of knowledge in clinical problem solving, applying this knowledge in practical settings is even more important. Experience with real patients is essential for developing 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). Mamede and Schmidt (2004) stated that practice alone, opportunistically,

would lead to exposure to a bigger pool of cases and therefore an increase in the number of illness scripts, or case templates used to match and solve new cases.

Many other theories indicated that experience alone was not enough to guarantee continuous development in the performance of CR. The basics of Kolb's (1984) Experiential Learning Theory is that people learn from experience not simply by an uncontrolled process of assimilation of the real world, but through a process of making sense of experience via reflection and action. This theory was largely influenced by the constructivist theories of Dennick (2008) but also was influenced by the work of Lewin (1951). This involved a control value theory in that individuals would not engage in effortful practice without significant motivation. However, that alone would not be enough. The learner also must identify new knowledge gains and new learning needs and repeatedly engaged in activity. In Ericsson's (2007) view, as in the early expertise studies of Elstein et al. (1978) and of Mylopoulos and Regehr (2011), experts are not simply those who have been repeatedly engaged in an activity – they are individuals who demonstrate superior performance in that same activity. Ericsson's (2006) theory of deliberate practice highlighted the timely feedback, coaching, and effortful practice necessary for achieving better performance. This not only means that practice has to be intentional and not opportunistic, but that it must be planned, evaluated, and redesigned based on identified learning needs and should represent a challenge.

Reflective practice was first described by Schon (1983). Some similarities can be found between Ericsson's (2004) notion of deliberate practice and the action planning component of Kolb's (1984) theory. According to Schon (1983), experts engage first in "reflection-in action" to make sense of an encounter, and later in "reflection-on-action" to learn from the encounter and enhance their clinical expertise.

Sandars (2009) stated that “reflection is a metacognitive process that occurs before, during or after situations with the purpose of developing greater understanding of both self and the situation to inform further actions” (p. 685). Reflection during a clinical encounter can change and improve the outcome of the encounter as it is occurring in real time (Cooper et al., 2016).

Therefore, Mamede et al. (2004) proposed a five-factor model of reflective practice in medicine. The five factors proposed by Mamede et al. (2004) were: (a) deliberate induction, (b) deliberate deduction, (c) testing and synthesising, (d) openness for reflection, and (e) meta-reasoning. Additionally, Norman et al. (2007) concluded that reflective reasoning seems to be as effective as non-analytic reasoning when dealing with routine cases. The above-mentioned theories, however, suggest that individual intentions, dispositions, and the structure of the experience influenced this learning process and can also influence the acquisition of expertise (Baker, Jensen, & Kolb., 2002; Ericsson, 2004; Kolb, 1984; Kolb, Boyatzis, & Mainemelis. 2000; Kolb and Kolb, 2005; Schon, 1983; Smith, 2001).

2.2.5. Role of Faculty Training

Dale and Dale (2017) stated that teachers’ guidance is crucial to the positive experiences and learning outcomes of nursing students, making the competence and preparedness of educators crucial to the outcomes of their students. While educational techniques that have been proven to improve CR are well explored in the literature, the lack of faculty expertise in teaching CR remains a significant barrier (Eva, 2005). Even if there is an outstanding educational program for CR, efforts will be compromised if faculty are not prepared to teach it, (DaRosa et al., 2012). With the changes in student population demographics come changes in teaching methods that must be factored into teacher training (Greenwald & Quitdamo, 2014). Supervising

clinical sessions are very important. Recommendations include supervisors aiming to encourage students to elaborate on their thinking and reasoning processes (Audétat & Laurin, 2010). Clinical teachers are responsible for promoting the development of CR in students through facilitating the connections between clinical features and basic knowledge and through assessing the level of its development throughout their clinical supervisions (Bowen, 2006; Cutrer et al., 2013; Irby, 1992; Zadik & Levin, 2007).

Through proper facilitations, students could develop a well-integrated, well-connected, validated, flexible, and adaptive body of knowledge that allow its mobilization (Boshuizen, 2003; Eva, 2005). Faculty need to develop the skills that will enable them to ask questions that emphasize components of the reasoning process and incorporate lessons (Holmboe et al., 2011). It is incumbent to have an effective faculty development program. Involving practicing clinicians in the teaching of CR may help improve their own abilities in CR (Durning et al., 2013). Practicing with experts who are good role models can also help to facilitate the development of CR skills in students (Ericsson, 2004; Smith, Joy, & Ellis, 2010).

Dalton et al. (2015) presented a suggestion that curriculum of medical education should contain activities and practicalities. The practicalities refer to the activities that require the students and learners to observe and learn about how to solve the problems of patients with the help and guidance of teachers and professionals. As per this study, it can be stated that curricula should not focus on the delivery of content and theory, but should concentrate on the provision of practices and exposures to the students. The experience, practicalities, and activities can enrich students' skills and confidence (Dalton et al., 2015). In addition, curriculum

developers should ensure that CR learners are engaged in real-life cases with proper supervision of clinical teachers.

2.2.6. Assessment of Clinical Reasoning Skills

Assessing CR has been attempted since the 1960's and 1970's (Amini et al., 2011; Van der Vleuten et al., 1995). Traditionally, domain-specific knowledge was the most important to do CR, with CR assessment being mainly directed toward assessing knowledge base information. However, this assumption can be challenged by the fact that CR is a construct that consists of multiple interacting elements. Therefore, 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 (Neufeld et al., 1981). There is no single tool for effectively measuring the CR process or end product. Instead, one should carefully consider the aim, objectives, and reasons for this assessment (Groves, 2002). Moreover, Schuwirth (2009) concluded that because CR and problem solving are highly domain specific and are not generic traits, the current methods for assessment are likely to fail since they rely on short cases and asking the students for essential decisions and since they are generic in nature. Assessing students for CR should come from many sources because it consists of multiple traits such as knowledge, skills, problem solving etc., with each trait best assessed by a specific tool.

Additionally, as with any other type of high-order cognitive process, CR is not accessible through direct observation. It can only be assessed indirectly through the analysis of its products or via individual verbalisation (Patel et al., 2005) as inference. Students' CR ability is inferred from their diagnostic accuracies and management

plans. Most assessments measure only the outcomes of CR via its end products (diagnosis and management) rather than measuring the process itself (Groves, Scott, & Alexander, 2002). There is a great difference between the process and the outcome of CR, and the same its true of its assessment.

Finally, medical education's existence as a multidisciplinary research field populated by researchers from several different backgrounds using different scientific paradigms, accepting a range of possible solutions to the same problem makes it a non-paradigmatic endeavour (Norman et al., 2009). There is no gold standard for the CR process and there are many acceptable solution paths to the correct answer. This is often called the idiosyncrasy of the problem solving and one of the challenges facing efforts to design an assessment tool for CR. Moreover, all the standardized assessments took place in artificial contexts and, as a result, could not assess all aspects of CR. Only the workplace-based assessment can be taken place in more authentic contexts. Workplace-based assessment has some limitations, but in order to assess all aspects of CR, combine standardized assessment with authentic workplace assessments are essential (Lang, Schuwirth, Durning, & Rencic, 2015).

Assessment can be done through stimulated recall, also referred to as retrospective thinking aloud protocol (Ericsson, 2006). The main critique for this method was that participant reports would be highly inaccurate since participants focused only on the end points once the task was finished and had difficulty reporting concurrent views that led to their conclusions (Ericsson, 2006). Additionally, scholars found that with this method, participants would reconstruct their own thought processes to match their own views regarding how they should be thinking, building after-the-fact reconstructions of their own performance (Ericsson, 2006). Because controlling for these self-generated explanations is virtually impossible, this method

was gradually replaced by other, more reliable methods. Thinking-aloud protocols, on the other hand, are concurrent with the performance of the task. This methodology and protocol analysis assumes that with proper training, individuals are able to produce verbalisations that will not affect their performance. This method proved to be a much more valid and reliable way of accessing mental processes (Ericsson & Towne, 2010), since the concurrent nature of the verbalisations allow a collection of data that includes the processes leading to the end products. In addition, all interpretation is done by the researcher rather than by the individual, thereby eliminating the possibility of retrospective self-reconstructions of the thought processes (Stefano, Borsci, & Stamerra, 2009).

Standardized assessment tools can also be used to assess CR, though they were not solely designed to do so. Standardized exams, like written exams or objective structured clinical exams, enable the assessment of all learners across the same predetermined set of problems and are capable of sampling a broad set of content domains within limited testing times. However, these methods place learners in artificial contexts and therefore don't assess all aspects of CR (Lang et al., 2015). Multiple choice questions (MCQs) are also commonly used in both high-stakes and low-stakes assessments of medical students. These questions can be formulated in a clinical vignette and the response is the single best answer. It has been argued that properly structured MCQs can be used to assess problem solving abilities. Advantages include the ease of construction, the high reliability, and the objectivity of marking. In comparison to questions with free test responses, MCQs can cue learners (Schuwirth, Van der Vleuten, & Donkers., 1996). Their low fidelity and susceptibility to measurement errors such as guessing are considered among their disadvantages (Kramer et al., 2009). This single-best answer response format limits the types of

questions, with locally developed exams yielding little valid data. Seif et al. (2014) added that MCQs do not address the understanding of complex, diverse, and severe factors underlying the profession of nursing or doctoring. Other standardized assessment tools such as extended matching items (Fenderson et al., 1997), oral exams (Burchard, Rowland-Morin, Coe, & Garb, 1995), concept maps (Lang, et al., 2015), or short answer essays (Kramer et al., 2009) can also be used to assess CR skills.

There are various assessment methods that can be used to assess CR (see Table 2.2). CR-specific testing tools include tests of diagnostic skills (TDSs). Rimoldi (1961) developed TDS with an aim of focusing on the process of problem solving rather than on the products. An examinee initially receives basic information of the clinical case, then, he/she may decide to ask questions about the case in order to reach a diagnosis (Rimoldi, 1961). Expert doctors can get to the diagnosis using less information than novices or students and can do so without asking as many questions, but instead asking more important or decisive questions (Van der Vleuten et al., 1995). The number and the order of the asked questions are considered in the analysis, in addition to a choice of not asking any questions. However, this assessment method has been criticised for its deficient validity. In addition, the scoring scale is sophisticated (Rimoldi, 1963). The basic assumptions were proved to be incorrect, as no generic problem-solving skills independent of knowledge were found in medicine, which further adds to its disadvantages (Elstein et al., 1978).

Patient management problems, at their core, have a long clinical case, with candidates being provided with patient scenarios and then asking the relevant history questions, performing the focus physical examination, and requesting the investigations (Rimoldi, 1961). This method is suitable for either individual or group

administration and also can be marked electronically (McGuire & Babbott, 1967). Its claimed advantages include high authenticity and face validity. Diagnostic Thinking Inventory (DTI) is clearly distinguished from all the others by not being a case-based instrument. Instead, based on participants' CR processes rather than measure of outcomes, the DTI is independent of knowledge (Bordage, Grant, & Marsden, 1990). DTI was designed to test two aspects of diagnostic thinking: the flexibility of thinking and knowledge organisation. DTI is designed to assess reasoning style and attitudes rather than yielding clinical realism (Groves et al., 2002).

The direct observation of clinical and procedural skills can also be accomplished. Observing students' performances when they deal with clinical cases, primarily in clinical settings or simulated settings, is a method used in the assessment of UG students' critical thinking and problem-solving abilities. Other skills can also be assessed, such as communication and professionalism. There are 55 different tools to use in direct observation of clinical skills (Kogan, Holmboe, & Hauer, 2009), with the Mini-CEX tool providing the most validity evidence. The Min-CEX tool is followed by a feedback session with the observer and the learner, though the subjectivity of rating is a major disadvantage commonly associated with this type of assessment (Kramer et al., 2009). The ability to correctly identify aspects of a learner's performance with direct observation can improve with training (Holmboe, 2004).

Table 2.2.
The Assessment Methods and Their Stimulus, Reliability, and Recommended Users

Standardized Multipurpose Assessment Tools							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
MCQ	Case vignette	Single best answer from a short list of options	High	High/low	Familiar to learners; predicts performance on future MCQ exams	Mixed effect of cueing; limited ability to predict clinical performance	Knowledge and CR: common and rare problems.
Extended matching items	Case vignette	Single best answer from a shared long list of options for multiple vignettes about a common topic	High	High/low	Tests pattern recognition		Diagnostic reasoning
Short-answer	Case vignette or question about comparing/ contrasting diagnostic or therapeutic approaches	Free text	Low-moderate	Moderate/ high	Avoids cueing; allows learners to explain their underlying reasoning	Limited breadth of content can be tested; faculty time to score the essays	Formative feedback; progress testing
Concept maps	Broad clinical topic	Diagram depicting relationship between features of the topic	Unknown	Moderate/ high	Identifies accuracy of illness scripts; avoids cueing	Requires training of learners; limited breadth of material can be tested	Structure and depth of knowledge on a single topic

Standardized Multipurpose Assessment Tools (cont'd)							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Oral exams	Case vignette, standardized patient, or real patient encounter	Verbal questions and answers; structured or unstructured	Low-moderate with structured interview and training	Moderate/ high	Avoids cueing; allows examiners to probe learners' underlying reasoning and ability to think on their feet	Biases of examiners	Ability to synthesize complex data and articulate thought process; formative feedback
OSCE	Trained actor portraying a patient using standard script	Checklist by observer or SP assessing history, physical, communication skills; post encounter note or form	Low-moderate	High/high	Assessment of application of knowledge and reasoning in standardized clinical scenarios	Requires training of standardized patient; scoring tool may overly reward thoroughness	Ability to select relevant data to gather while conducting a history and physical examination; involvement of patient shared decision-making
Purposely designed CR assessment tools							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Test of Diagnostic skills (TDS)	Preliminary information about a case and Group of cards with additional information about the case	Against the group norms and 'intrinsic' difficulty of each problem	Unknown	Moderate	Authentic, involves in all clinical cycle	Deficient validity	CR using a deductive reasoning strategy

Purposely designed CR assessment tools (cont'd)							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Programmed Tests	Clinical case booklet	Scored by the correct decision	Unknown	Complex to develop and score because of the "correct decision" factor	Authentic, involves in all clinical cycle, used with large samples	Measure knowledge rather than CR.	Clinical judgement
Simulated patient-problem technique	Clinical case booklet	CI (competence index) = {(Proficiency index x Efficiency index/100) + PI} 2 The answer sheet provides feedback and a record of management	Unknown		Make clinical decisions like those he would make in his practice.		CR
Case Study problem	Clinical data-booklet	The scores were based in experts' opinions about the pertinence of the 100 items of page 3 from +5 to +1 or 0 for no relevance.	Low-moderate	Low-moderate	Capable of evaluating cognitive capacities beyond those of discrimination of investigation results	Not easy to score. No information about the patients, focused on interpretation of the test results	Interpretation and application of lab studies

Purposely designed CR assessment tools (cont'd)							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Patient Management Problem	Many forms: Problem box/ Portable Patient Problem Pack (P4) deck that consists of a sequence of choices made upon an initial patient description	The pathway though the problem is determined by the choices of the student. All relevant information elicited by the candidate plus the correct diagnosis and therapy were scored	Low	Low	All the components of clinical cycle	Low validity, Idiosyncrasy,	CR
Diagnostic Thinking Inventory (DTI)	consists of 65 (now 41) items, and each item contains a stem followed by a 6-point semantic differential scale	Self-reported scale. Marks are calculated based on the proximity of the chosen point to that of experts	Moderate/high	Low	Recognition of meaningful information, definition of clinical data and access to knowledge structure	Self-reported, individual variables may impact on the result. Not directly to a specific task	Reasoning style/ flexibility of thinking/ medical knowledge structure
Key features exam (KFE)	Case vignette	Free texts or select from a list of options and "poison responses"	Moderate/high	High/low	Feasible approach to the complex reality of clinical tasks and predictive performance in clinical practice	Significant training required to develop exam and complex marking scheme	Reasoning focus on crucial elements to handle the case

Purposely designed CR assessment tools (cont'd)							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Script concordance test	Case vignette	Weighting of how new data affect the likelihood of a hypothesis on 5-point Likert scale.	High	High/low	Authentic, allows partial credits for choices where experts reasonably disagree	Difficult to mark or standard set	Capacity to interpret new information in ill-defined problems/ in the context of uncertainty.
Comprehensive Integrative Puzzle (CIP)	Case vignette	Extended matching crossword puzzle	Moderate/ High	Unknown	Integrating biomedical disciplines and CR	More research is needed to have a clear picture of its weaknesses	Diagnostic thinking and CR, interpreting medical history data, physical examination findings, laboratory test results
Clinical Reasoning Problem	Case vignette	Free text development of hypotheses; weighing of how each key finding affects each hypothesis on Likert scale	Unknown	High/low-moderate	Identifies accuracy of illness scripts; avoids cueing of differential diagnosis	Limited to diagnostic reasoning, not management; cueing of key findings	Diagnosis knowledge/ Illness scripts
High-fidelity simulations (with technology assistance)	Mannequin or task trainer, with or without confederates	Observation of trainee performing history, physical, or procedures; managing illness in real times; checklist or global assessment form	Low-Moderate	High/high	Assessment of clinical decision making in rare but important scenarios	Requires trained staff to operate equipment and act as confederates	Ability to make in real time, especially in critical situations; communication with interdisciplinary team in decision making

Purposely designed CR assessment tools (cont'd)							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Virtual learning patients (VLP) and Virtual reality	Interactive Case Vignette, different kind of situations	Make decisions	Unknown	High	Unknown New innovation	Unknown	CR
Work place Assessment							
Assessment Methods	Stimulus	Response	Reliability	Resource Intensity	Advantages	Disadvantages	Recommended Uses
Chart-stimulated recall	Documentation of encounter with a real patient	Verbal questions and answers; unstructured	Unknown	Low-moderate	Allows examiners to probe learners' underlying reasoning	Medical decision-making may reflect other physician's decisions	Formative feedback to learners with high level of independence
Oral case presentations	Presentation about a real patient	Unstructured or structured	Unknown	Low-moderate	Readily available; woven into patient care and instruction	Breadth of topics limited by available patients; influence of other physician' input	Formative feedback
Direct observation of clinical or procedural skills	Real task with real patient	Scoring form (e.g., Mini-CEX)	Low-moderate	Low-high	Readily available; woven into patient care and instruction	Making mutual convenient time for learner, patient and observer and training for observers	Ability to select correct data to gather while conducting a history and physical examination; involvement of patient in shared decision-making; formative feedback
Global assessment	Interactions over the course of a clinical rotations	Narrative comments or Likert scale	Low-moderate	Low-moderate	Readily available; woven into patient care and instruction	Affected by the factors unrelated to the learners	Summative assessment for end of rotation

2.2.7. Drivers of Change

Kong et al. (2014) stated that students have not necessarily been provided with sufficient information and education regarding reasoning skills and that their development of reasoning skills in nursing and medical education has not been adequate. CR can be acquired by experience during the students' training, though researchers conclude that it is more difficult now for medical students and junior doctors to acquire CR skills than it was for students 10-20 years ago (Durning et al., 2011; Ledford et al., 2015; Hammond & Henderson, 2015; Caldwell, 2013). These include the fact that many medical school curricula are function in silos. For instance, on cardiology attachment, seeing a patient with chest pain the diagnosis is likely to be due to cardiovascular disease (Hammond & Henderson, 2015). The implementation of the European Working Time Directive and shift systems mean that not only do doctors work fewer hours, they also experience a loss of team structure (Hammond et al 2015). And the current NHS workload pressures also squeezed the times of teaching, learning and reflection. Over half of physicians surveyed said the time they had available to spend with trainees had decreased over the past three years (Royal College of Physicians Census, 2010).

Trainees value high-quality supervision that includes feedback and performance assessment, though many receive no formal feedback and have concerns about the quality of assessment (GMC National Training Survey, 2011). The syllabus is ever expanding, with each vested speciality pressure group arguing that their diseases are the most important. This makes the knowledge section of the syllabus increasingly voluminous, resulting in shorter and more fragmented attachments that provide patient experience (Caldwell, 2013). Opportunities for CR practices are also limited by a lack of longitudinal follow-up on the patient journey, by fact paced

modern clinical care with short hospital stays, and by frequent transitions to different specialities. The Institute of Medicine (2000) published a report entitled "Diagnostic Error in Healthcare" that prompted a massive change in healthcare quality around the world.

Diagnostic errors stem from a variety of causes. A comprehensive review of studies of misdiagnosis assigned three main categories: no fault error, system failures, and human cognitive errors. However, it has been estimated that roughly two-thirds of the root causes of diagnostic errors involve errors in reasoning (Cooper, 2015). This means that sound CR is directly linked to patient safety and quality of care and that it's teaching should be a priority.

The diagnostic error may be reflected in an incomplete knowledge base or inadequate experience. The knowledge gap theory is supported by research that showed correlation between diagnostic accuracy and previous experience with similar cases and between diagnostic accuracy and formal knowledge measured by written examinations. Linked to the knowledge gaps, the second issue involves misinterpretation of the diagnostic tests, of the patient's history, and of examination findings. The third problem is cognitive biases, or cognitive dispositions, in responding to certain situations. (Cooper, 2015). The remedies for diagnostic error are therefore to increase knowledge and diagnostic skills through greater experience, deliberate practice, corrective feedback, and cognitive forcing strategies. The Institute of Medicine (2000) highlighted key recommendations in their report to include explicit training for healthcare professions in the diagnostic process, emphasizing the importance of team connection in the diagnostic process and of properly involving the patients and/or carers in the information gathering process. Doing so would establish a work system and culture that supports the diagnostic process and would develop and

deploy approaches to identify, learn from, and reduce diagnostic errors and near misses (Cooper, 2015).

The CR curriculum should also be designed and established on the basis of national needs and priorities required for medical teaching and learning (Jamieson, 2015). Jamieson (2015) presented the stakeholders' prospects of teaching and assessing CR through an analysis of regulatory bodies' websites, documents, and curriculum outcomes to look for what these organizations said about CR. The GMC is one of the main organisations that set the principles, requirements, and standards for inclusion in medical training and education. However, nothing was specifically stated concerning CR in "Promoting Excellence: Standards for Medical Education and Training," which replaced "Standards for Delivery of Teaching, Learning and Assessment for UG Medical Education" in *Tomorrow's Doctors* and in *The Trainee Doctor* (Posel, Mcgee, & Fleiszer; 2015). The GMC has asserted that it is important to include learning opportunities that are based on the clinical and basic sciences that enable and empower students to associate their theoretical knowledge with medical practice, saying "Medical school curricula must give medical students: learning opportunities that integrate basic and clinical sciences, enabling them to link theory and practice" (p. 33).

This implies a promotion of clinical-based learning where students should be educated using case scenarios and asked to relate their clinical observations, assessments, and findings to their experiences and knowledge in order to make decisions and provide a clinical diagnosis. Students should be encouraged to discuss these with their colleagues in order to determine the effectiveness of communication and decision-making. The most relevant literature from the GMC related to CR is

found in the "Outcomes for Graduates" from *Tomorrow's Doctors* (2015). The outcomes are as follows:

- **Outcome 1:** The doctor as a scholar and a scientist, 8 (c): "Justify the selection of appropriate investigations for common clinical cases" and 8 (g): "Make accurate observations of clinical phenomena and appropriate critical analysis of clinical data" (p. 2)
- **Outcome 14 (f):** "The medical graduate must be able to make clinical judgments and decisions, based on the available evidence, in conjunction with colleagues and as appropriate for their level of training and experience." (p. 5)

In another GMC (2017) document, "Developing A Framework for Generic Professional Capabilities, A Public Consultation," there are some statements that may relate to CR, specifically:

- **Domain 2.** Professional skills, clinical skills, History taking, diagnosing and medical management.
  - "Show appropriate CR by analyzing physical and psychological findings"
  - "Explain CR behind diagnostic and clinical management decisions" (p. 14)

The complete training and experience of medical graduates should be in conjunction with the colleagues and other fellow graduates in order to ensure better CR competencies (Barton et al., 2015). The Scottish Deans' Medical Education Group (SDMEG, 2008) also has described the standards for the curriculum for CR and has highlighted the importance of decision-making in "The Scottish Doctor: Learning

Outcomes for the Medical UG in Scotland: A Foundation for Competent and Reflective Practitioner."

One domain out of 12 learning outcomes is "Decision Making Skills, and CR and Judgement" (1.2.1 Phase 1: The specification of learning outcomes). The original Scottish Doctor outcomes were developed using a hierarchical framework of four levels, each of which (from high to low) provided progressively more detail. Learning outcomes for the above domain include: decision making skills, CR, and judgement.

- **Level 1.** "How the doctor approaches their practice"
- **Level 2.** "Outcomes for Decision Making Skills, and CR and Judgement"

Decision-making, CR, and judgement are activities in which medical UG should be proficient. The new medical graduates must continue to display and develop such skills, along with bearing the additional burden of increasing responsibility for their decisions and actions. This is undoubtedly one of the most stressful aspects of the transition between UG and foundation practitioner, but the achievement of these outcomes to a high standard is essential (SDMEG, 2008).

- **Level 3 (1):** Critical reasoning.
- **Level 4 (1):** "How to recognise and define the problem, analyse and interpret information, cope with limitations of information and personal limitations and find appropriate solutions."
- **Level 3 (3):** Critical thinking.
- **Level 4 (3):** Adopting an inquisitive and questioning attitude where appropriate and applying rational processes. Recognising the significance of value judgements and that those of doctor and patient may differ.

Although it is not explicitly mentioned as CR, there are many statements in Level 3 and Level 4 outcomes of other domains that are related to CR. For example, in 'Learning Outcomes for Clinical Skills:"

- "History taking in patients from all age groups taking into account local multicultural/multi-ethnic factors and a wide range of different contexts"
- "Interpret results of history taking, physical and mental state examination and investigations"
- "Recognition of abnormality and correct interpretation of common investigative tests. Requesting appropriate investigations"

The curriculum should provide a platform for the medical students to develop clinical learning and judgments skills that can help them in their professional life (Kurtz, Silverman, & Draper 2016). Swanwick (2010) stated that the learners must know how to interpret the findings and observations of a patient and have the potential to decide on the basis of clinical knowledge and evidence. SDMEG emphasised clinical judgment, decision-making skills, and CR skills as the most important abilities needed for medical students.

In post-graduate environments, the Royal College of General Practitioners (RCGP, 2015) applied a scientific and evidence-based approach, saying that GPs should:

- "Maintain a sufficiently broad and detailed knowledge of the science relevant to your role… [including] decision-making, reasoning and problem-solving theory."
- "Use the best available evidence in your decision-making, applying critical thinking to appraise the literature, recognizing the strengths and limitations of evidence-based guidelines"

- "Apply knowledge of the epidemiology of disease to your decision-making, including the age/sex distributions, risk factors, relevance, incidence, and the relevant characteristics of 'at-risk' groups" (p. 26).

Although each statement is not specifically mentioned as CR, these words are based on CR: problem solving, decision-making, and using the prior knowledge in order to make clinical decision. The RCGP (2015) also provided professional and clinical modules in which it mentioned reasoning:

> "Within this framework health professionals make decisions that require application and interpretation of professional codes of conduct to the circumstances of particular cases or situations. To do this health professionals must be able to identify ethical issues arising in practice, evaluate the moral reasoning for different courses of action, and justify [your] decisions" (RCGP, 2015, p. 6).

The Royal College of Surgeons in England (RCSEng, 2014) explicitly mentioned CR in "The Curriculum Framework for the Surgical Care Practitioner (SCP)." The college focused on progression in CR through appropriate measures of training and supervision. The college further emphasized that clinical based discussion helps the medical graduate to better evaluate the patient's situation and apply relevant medical knowledge to the situation for sound decision making and rational approach toward the solution (Posel et al., 2015). Professional and educational values underpinning the philosophy of the curriculum include that SCPs should have the ability to:

- "Exercise CR and develop professional judgment in their practice." (p.18)

RCSEng clearly stated in "Assessment and Supervision of Progression Through Training" that determining level of supervision required for trainees includes:

- "Assessment of knowledge and reasoning." (p.32)

Level of competence and practice of trainee SCPs is mapped against Intercollegiate Surgical Curriculum Programme domains and the clinical supervisor must be satisfied that a trainee has fulfilled the descriptors within "assessment of knowledge and reasoning" perspectives in order to deemed to be performing at each level (p. 33). At the progression point at end of Year 1, a trainee must "apply accurate knowledge to practice, have some awareness of alternatives and begin to make judgements based on contemporary evidence" (p.33). At the progression point at exit of training, a trainee must be able to "apply evidence-based knowledge, demonstrates awareness of alternatives, gives sound rationale for actions, make judgements and decisions based on contemporary evidence" (p.33).

RCSEng (2014) clearly mentioned the specific tools for formative assessment of progression and completion of SCPs. This assessment enables the students to be proficient in medical history taking, assessment and examination, and provide CR.

- "Case based discussion (CBD) evaluates a performance in the management of a patient to provide an indication of competence in areas such as CR, decision-making and application of medical knowledge in relation to patient care. It enables and serves as a method to document conversations about, and presentations of, cases."
- "Clinical Evaluation Exercise (CEX) evaluates a clinical encounter with a patient to provide an indication of competence in skills essential for good clinical care such as history taking, examination and CR. This allows students to receive immediate feedback on their learning." (p. 39-40)

The curriculum of CR should include CBD and Clinical Evaluation Exercise (CEX). RCSEng (2014) also emphasises on the use and inclusion of learning of these assessment tools in the curriculum. PBL and CBD are the ones that underline the

competence of the student in different medical areas such as decision-making process, CR, and implication of medical knowledge in assessing and providing care to the patient (Savery, 2015). Furthermore, the CEX in the college helps to evaluate the encounter with the patient and indicate the competence level of medical student in the field with assessment of CR and examination skills.

Medical students, trainees, and practitioners are expected to develop and use CR skills. Van der Vleuten and Newble (1995) emphasised:

> All health professionals in all countries should be educated to mobilise knowledge and to engage in critical reasoning and ethical conduct so that they are competent to participate in patient and population centred health care systems as members of locally responsive and globally connected health care teams. (p.1033)

Research commissioned by the GMC and entitled "Work Activities Performed by Doctors in The Foundation Programme" was published in September 2015 and demonstrated that the following activities mainly under the type of clinical judgements and others were a regular part of the job during F1 and F2 years (frequency shown in brackets): GMC (2015)

- making an initial assessment of patient's problems (93%);
- formulating differential diagnosis (93%);
- interpreting findings from history and examination (98%);
- interpreting investigation results (97%);
- establishing a problem list and likely diagnosis (93%);
- seeking advice from other health professionals in situations of clinical uncertainty (98%);
- making clinical judgements and decisions in conjunction with colleagues (97%);
- formulating a plan of investigation (94%);

- formulating a plan of treatment and management (95%);
- helping a patient make decisions about their care (84%); and
- formulating a discharge plan (86%)

Hence these guidelines, curriculum, regular activities of junior doctors and practices at Royal college of Surgeons, and the guidelines provided by GMC are evident for the importance of CR. They provided a national priority for the medical graduates to be self-sufficient and capable for CR.

As a result, the fundamental priorities of the university are to improve the curriculum of the university. In this regard, the universities tend to upgrade and improve their curriculum for meeting the previously developed standards (Ahmed & Alneel, 2017). Medical education is referred to as the dynamic process, and the curricula of medical schools need multiple reviews and amendments for dealing with the continuous changes in the medical field (Swanwick, 2010). Considering the context of curriculum design of medical schools, it is clear that the inclusion of CR within the curriculum will assist students in making accurate observations and enable them to perform appropriate critical analysis of clinical data. Hence the curriculum must be designed with the intention of improving the CR skills of medical students (Ahmed et al., 2017).

Brauer et al. (2015) as well as Pinnock and Welch (2014) considered that changes are required in the clinical education system for the core purpose of implementing a framework of high-quality standards. Superior educational standards provide a vision for excellent learning and teaching, but Mariani et al. (2013) argued that vision cannot be realized until the standards infuse change within educational system and design curriculum development at priority. On a similar note, Irby (2014) and Delany and Golding (2014) signified that instructional change must be prioritized

in classrooms with best teaching practices accompanied by pioneering discoveries about clinical learning. Tierney et al. (2013) stated that UG students are unable to understand the complex problems of patients when provided placements at hospitals. In other words, they are unable to play the role of their jobs because of the inefficiency of the medical curriculum taught to them. Therefore, the future direction of CR can be the inclusion of comprehensive understanding of complex problems that are expected to be solved by the healthcare professionals. Buery-Joyner et al. (2015) argued that understanding of the complex problems existing in the real world and in the profession of nurses must be made a part of learning objectives of CR teaching.

2.3. SUMMARY

Despite the breadth of literature around clinical reasoning, its key models and theories, and its influence on medical practice, there continues to be a lack of understanding about the curriculum design that best works for formally introducing CR training and education in the educational landscape of undergraduate students seeking a medical degree. There are also studies about the importance of knowledge, learning approaches, and faculty training on the efficiency of a medical curriculum. However, a gap remains in existing literature regarding how CR can be effectively introduced in the UG curriculum and a lack of evaluative research focused on the efficiency of different curriculum designs, with particular focus on CR skills training at the UG level.

UoN has begun its efforts toward introducing CR-oriented curricula among its UG students. While the process of planning, design, implementation, and feedback has been consistently followed, there is no consensus on the effectiveness of CR education in the university. Thus, there continues to be a need for a systematic

assessment of the effectiveness of the CR curriculum at the UG level among students and clinical teachers at the UoN.

CHAPTER 3 METHODOLOGY

The methodology of this study consisted of developing and implementing the CR curriculum and then evaluating the curriculum through a mixed of quantitative and qualitative methods. In this study, the researcher focused on understanding the development, implementation, and integration of a CR curriculum into the medical curriculum for UG students at the UoN. The researcher also evaluated the effectiveness of this curriculum strand through a mixed-methods approach. In this chapter, the researcher details the setting of the study, the research design chosen, and the rationale behind the choice. The chapter also includes an explanation regarding the role of the researcher in the process as well as the methodology employed to achieve the goals of the study, including the data collection and analysis processes. The researcher also addresses the possible limitations of the methodology in this chapter.

3.1. BACKGROUND

The methodology of this study involved monitoring all the planning, implementing, and devising of evaluation tools for the CR curriculum as well as evaluating the teacher training programme. Some of these elements were initiated and developed by the researcher and some were happening independent of researcher intervention. In the latter situation, the researcher identified the area of change and the way it was embedded.

Table 3.1.
The Research Timeline and Data

	Data collection method	Time of data collection
Developing, implementing and evaluating Year 1	Data from the meeting minutes	2011-2012
	Students' feedback	
Developing, implementing and evaluating Year 2	Data from the meeting minutes	2012-2013
	Students' questionnaires and interview	
Developing, implementing and evaluating Year 3	Data from the meeting minutes	2013-2014
	Students' questionnaires and interview	
Developing, implementing at GEM	Gather information from GEM team	2016
Evaluating CP1	Students' exam data	2012
Developing, implementing and evaluating CP1	Data from the meeting minutes	2013
	Students' questionnaires and interview	
	Students' exam data	
Evaluating CP1	Students' exam data	2014
Evaluating CP3	Students' exam data	2014
Developing, implementing and evaluating CP3	Data from the meeting minutes	2015
	Students' questionnaires and interview	
	Students' exam data	
Evaluating CP3	Students' exam data	2016
Learning needs analysis	Students and teachers interview	2015
Developing, implementing and evaluating the Teachers training programme.	Data from the meeting minutes	2016, 2017, 2018
	Participants' questionnaires	

3.1.1. Setting

UoN served as the setting for this study because the school was currently in the process of introducing a CR curriculum. It was important to analyse, measure, and evaluate the integration of the CR curriculum as it was being vertically integrated from Year 1 through the whole curriculum. As the process of developing the CR curriculum was only in its early stages, this provided an opportunity to assess the effectiveness of and inform the process for the future.

3.1.2. Research Design and Rationale

Few researchers have created developmental or longitudinal studies aimed at understanding the development of CR at the UG level. The present research project aimed to add to the body of knowledge within this field of research by exploring the impact of different curricula used at UoN on the development of awareness of CR and to examine how students develop their understanding of CR in the first and third clinical years. This study focused on exploring students' and teachers' understandings of CR, their development of CR skills, and the impact of the learning opportunities. This study was guided by the following eight research questions:

RQ1. Is CR being embedded explicitly in the curriculum?

RQ2. How effective is the new curriculum in developing the CR skills of the students and in developing the CR teaching skills of the clinical teachers?

RQ3. How do the students learn/develop CR?

RQ4. Does the curricular phase of the curriculum have an impact on the development of CR?

$H0_1$: There is no significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

Ha_1: There is a statistically significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

RQ5. Does the participation in CCS CR teaching curriculum model influence outcomes as measured by summative written exams?

$H0_2$: There is no significant effect from the participation in CCS CR teaching.

Ha_2: There is a statistically significant effect from the participation in CCS CR teaching.

RQ6. Does the redesign of the course each year improve the performance CR?

$H0_3$: There is no significant effect from the CR teaching/implementation process.

Ha_3: There is a statistically significant effect from the CR teaching/implementation process.

RQ7. Does gender influence outcomes as measured by summative written exams?

$H0_4$: There is no significant effect from gender on outcomes as measured by CR score in the summative written exams.

Ha_4: There is statistically significant effect from gender on outcomes as measured by CR score in the summative written exams.

RQ8. Do graduate entry PBL students receive better CR score than UG integrated students?

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

The researcher employed both quantitative and qualitative components to pursue answer to the research questions and to address the goals of the study. Durning et al. (2011) referred to the difference between qualitative and quantitative researchers by stating that a qualitative researcher aims to uncover patterns that emerge from the data, while a quantitative researcher makes a guess or forms a hypothesis, which is then used to further test the data. The mixed-methods approach of this study was selected based on the assumption that the pragmatist approach to mixed-methods research would allow this researcher flexibly chooses the appropriate methods for answering the research questions (Brierley, 2017). When there is a need for a deeper explanation of numerical results, a mixed methodology combines qualitative explanation with quantitative data or findings (Moissenko, Braicu, Tomuleasa, & Berindan-Neagoe, 2016). Mixed-methods research enables the integration of quantitative and qualitative research approaches, with pragmatism offering an alternative perspective from post-positivist and constructivist approaches to research. Pragmatism allows researchers to incorporate the unpredictable human forces that

influence measurable data (Feilzer, 2010). Mixed-methods research uses quantitative and qualitative techniques within the same framework, incorporating the strengths of both methodologies. Researchers who use mixed-methods approaches are likely to employ processes that are aligned to their research questions instead of focusing on a pre-conceived idea regarding the particular research paradigm that has hegemony over the topic at hand. The pragmatic approach promoted by mixed-methods research views knowledge as being both constructed and based on reality (Burke Johnson & Onwuegbuzie, 2004).

Researchers use qualitative methodology when the purpose of the study requires investigation or deep exploration of people's perception and interpretation of a phenomenon (Moissenko et al., 2016). For the qualitative portion of this study, the researcher explored the attitudes, views, behaviours, understandings, practices, and experiences of students and teachers through interviews or focus groups, gathering in-depth opinions from participants. Such research usually begins with questions regarding the nature and characteristics of a phenomenon focusing on meaning and understanding. The end product of qualitative studies includes detailed descriptions. Qualitative research can be referred to as interpretive research since it is concerned with how people interpret their experiences and social phenomena (Pope & Mays, 2006).

A qualitative researcher seeks patterns in data, while quantitative researchers use data to form and test hypotheses. Thus, the scientific approach is to collect quantitative data and then generate statistics through various methods of analysis in order to understand the population under study (Allen, 2017). In this study, the researcher explored an understanding of the students' evaluations of learning events and of the usefulness of the learning events in terms of exam results, with the learning

event in this case being a course on CR. The researcher examined the CR marks of students' summative exam papers from six cohort groups: CP1 for the years 2012, 2013, 2014 and CP3 for the years 2014, 2015, 2016.

There are multiple approaches to quantitative research and at the heart of each is the assemblage of data. This can be done on a secondary level, with the researcher using data collected by others, or it can be done on a primary level, with the researcher collecting data directly for the study. In terms of the former, the researcher obtained summative test scores and results. Data analysis takes many forms, with quantitative analysis being generally focused on obtaining statistics that describe relationships and interactions in the data. To that end, quantitative research relies on testing hypotheses about the relationships in the data that are then tested using various statistical methods (Taheri, Porter, Konig & Valantasis-Kanellos, 2015).

3.1.3. Role of the Researcher

The researcher was actively involved in developing, implementing and evaluating all aspects of the CR curriculum. For the curriculum development phase of the study, the researcher participated as a member of the curriculum committee, working in collaboration with the teachers and other members of the curriculum committee to develop resources for the teaching of CR across the curriculum. These educational resources were evaluated each year by student feedback. The researcher designed a short questionnaire to elicit students' thoughts about the curriculum.

For the qualitative portion of the study, the researcher served as the central instrument for data collection (Corbin & Strauss, 2014). The researcher was responsible for selecting the participants, collecting interview data, and conducting the analysis of the interview transcripts. During recruitment and selection of

participants, the researcher used a set of eligibility criteria as the basis for identifying whether an individual could participate in the study.

As the main instrument for data collection, the researcher conducted the interviews with the participants. During the data collection phase, the researcher used an interview guide to ensure the structure and alignment of the questions to the topic of the study. The researcher personally developed the questions in the interview guide. However, experts reviewed the questions to ensure that the word usage, the structure, and the content of the questions were aligned with the topic and the intended users of the interview guide. The researcher then conducted the coding and thematic analysis to generate relevant themes that were needed to accomplish the qualitative objectives of the study. In order to ensure reflexivity in the research process, the researcher was transparent in regard to all the decisions made at every step of the study (Attia & Edge, 2017).

3.2. THE METHODOLOGY OF THE CURRICULUM DEVELOPMENT

This section highlights the methods for developing the resources for teaching and assessing CR across the UoN curriculum. The curriculum committee and individual teachers developed some of the resources. The researcher created and initiated some of them in collaboration with the committee.

3.2.1. Introduction to the Clinical Reasoning Curriculum of University of Nottingham

UoN has sought to constantly evaluate and improve its medical curriculum since its foundation in 1974. The school has established mandatory requirements that students of medicine be proficient in CR in order to successfully pursue their careers. UoN has focused on the inclusion of CR programs within its curriculum. The CR programs allow the students to develop critical thinking skills (Kulasegaram et al.,

2013). The university has designed its curriculum in the context of seeking to make sure that students also realize the social responsibility and social purposes of their roles in society (Cheung, 2014). In order to introduce the CR theme at UoN, the school of medicine's course structure and background of curriculum must be understood.

UoN has a strong reputation for both clinical medicine and teaching. As one of the most popular medical schools in the country, it is able to select excellent students and produce and attract good junior doctors. Entry-level medical education programs are tertiary-level courses attempted at a medical school. These programs may be either UG entry, as is the case in the vast majority of Europe, Asia, South America and Oceania, or can be graduate-entry, as is the case primarily in Australia and North America (Posel, Mcgee, & Fleiszer, 2015). A few purviews and colleges give both undergraduate entry projects and graduate entry programs (Australia and South Korea, specifically). UoN is one of those entities. The university's School of Medicine trains tomorrow's doctors on a UG medical course with a unique intercalated BMedSci, as well as in a specialised graduate-entry programme built around clinical problem solving. UoN teaches medicine and related disciplines at both UG and postgraduate level.

There are three routes at UoN by which medical students graduate as doctors: the five and six-year UG courses (A100 and A108) and the graduate-entry, four-year course (A101). For all three tracks, the educational objective is the same: to acquire the knowledge, skills, and behaviour to allow graduates to practice as new doctors on the foundation training programme with the Bachelor of Medicine/Bachelor of Surgery degree. In addition, all students on the five-year and six-year courses obtain a BMedSci degree. For students wishing to become doctors, UoN offers a five-year UG

course that is accredited and mapped to the outcomes for graduates specified by the GMC (2015; 2016) in the documents “Outcomes for Graduates” and “Promoting Excellence: Standards for Medical Education and Training.” Application must be made through the Universities and Colleges Admissions Service, a UK-based organisation whose main role is to operate the application process for British universities). Admission to this medical degree is also a very competitive process, with students being selected based on their exam grades in secondary education exam results (General Certificate of Secondary Education and A-levels), their score in the UK Clinical Aptitude Test (UKCAT), and their performance in a multiple mini interview (MMI) process. The UKCAT is a test used in the selection process by a consortium of UK university medical and dental schools to make more informed choices between medical and dental applicants. It was first introduced in 2006. The test is designed to give information on the candidates' cognitive abilities through four reasoning tests, with a fifth test, the situational judgement test testing attitudes and professional behaviour. The MMI process has replaced the traditional interview style because it is believed to be a better predictor of professional behaviour and can explore themes in different ways.

<table>
<tr><td>Six year undergraduate course
(A108)

o Biological Molecules
o Body Structure
o Health, Behaviour and Society</td><td></td></tr>
<tr><td>Five year undergraduate course
(A100)</td><td>Four year (Graduate Entry to Medicine, GEM) course
(A101)</td></tr>
<tr><td>Years 1 and 2
(Semesters 1-4)

o Basic Medical Sciences
o Clinical & professional development
o Some advanced biomedical science options in Semester 4</td><td rowspan="2">First 18 months

o Problem based learning (PBL) course
o Clinical & professional development</td></tr>
<tr><td>Year 3

Semester 5

o Research project
o Research methodology
o Advanced biomedical science options
o Infections course</td></tr>
<tr><td colspan="2">Year 3 - Semester 6 (5yr course) & Year 2 (4yr GEM course) CLINICAL PHASE 1

Clinical practice (Medicine & Surgery) and Community follow-up project, Infection and Therapeutics</td></tr>
<tr><td colspan="2">Year 4 (5yr course) & Year 3 (4yr GEM course) CLINICAL PHASE 2

Child health, Obstetrics & Gynaecology, Psychiatry, Health Care of Later Life, Dermatology, Ophthalmology, ENT (DOE), Community Based Medicine, Special Study Module</td></tr>
<tr><td colspan="2">Year 5 (5yr course) & Year 4 (4yr GEM course) CLINICAL PHASE 3

Advanced Clinical Experience (Medicine, Surgery, Critical Illness, Musculoskeletal Disorders and Disability, Primary Care) and Transition to Practice (Medical Assistantship, Elective Study Period, Preparation and shadowing for Foundation Years)</td></tr>
</table>

Figure 3.1. Structure of the medical curriculum from 2016/17 handbook.

3.2.2. The Pre-Existing Course Structure of the Medical Curriculum in the University of Nottingham

The overall course has a pre-clinical component and a clinical component. The first part of the course (A100) comprises learning and teaching in core and advanced biomedical and social sciences, clinical skills, and early clinical experience, resulting in the award of the classified Honours degree of Bachelor of Medical Sciences at the end of the third year. This part of the course is based in Nottingham. The

BMedSci/BMBS medical degree complete an integrated BMedSci in third year, allowing to undertake a supervised research project without studying an extra year and gain early interaction with patients through regular visits to general practices and hospitals. The UoN medical school was established in 1970, with a current admission of 206 students plus 25 international students, and with 25 students progressing from the foundation course per year. The learning and teaching in the second part of the course (A100) concentrates on full-time clinical training. At the end of this period, successful students are awarded the Bachelor of Medicine and the Bachelor of Surgery degrees. The last portion consists of instruction in the different areas of clinical medicine.

A six-year Medicine with a Foundation Year Course (A108) has been designed to widen access to higher education. It is designed to for the instruction of 27 students per annum who wish to study medicine but who do not meet the normal requirements for entry onto the A100 course and haven't previously studied at a higher education institution. The A108 students also must meet other participation criteria, including having a home postal code for a less advantaged neighbourhood, living in Local Authority care, having a household annual income below £35,000, or having refugee status. This is a one-year foundation course from which successful participants automatically progress to the BMBS Medicine course to join year-one students on the five-year A100.

A Graduate Entry Medicine (GEM) course (A101) is also delivered by the UoN in partnership with Derby Hospitals NHS Foundation Trust, and is based in a medical school on the Royal Derby Hospital site. This four-year medical course commenced in September 2003 and is open to graduates of any discipline. The selection of the candidates is done via the Graduate Australian Medical School

Admissions Test (GAMSAT) examination plus an MMI interview process. The role of the GAMSAT exam is to assist in the selection criteria for students who are applying to study medicine on the new fast-track graduate entry programmes. It is designed to assess the students' capacities for undertaking high-level intellectual studies in the medical and health profession programs. Students must engage in PBL, using clinical scenarios to build their knowledge. These are supported by taught classes such as lectures, workshops, and clinical skills sessions. Early clinical experience is provided in clinical settings and personal and professional development is encouraged. The course is divided into modules, each of which examines a different system of the body. Working in groups, students study the underlying science, physiology and wider issues presented by a case study each week. There is an annual intake of 93 home/EU students. On successfully passing examinations at 12 months and 18 months, these students then join the A300 programme for the remaining 36 months of their studies. This course does not admit overseas students. A300 begins in semester four for A101 (GEM) students and in semester six for A100 students. It is the beginning of the clinical attachment components of the medical course.

For CP1, students spend 17 weeks in one of five partner NHS sites – Derby, Lincoln, Nottingham City, Nottingham QMC, or Kings Mill (Mansfield). During this time, students are taught the basic principles of taking histories and undertaking clinical examinations in both medicine and surgery placements. At the end of the attachment, students undertake a knowledge based MCQ examination and clinical skills examination. Students failing these examinations in June are permitted to progress conditionally into CP2, but are required to re-sit them in August of the same year. For CP3, four 10-week placements cover a range or specialties such as obstetrics and gynaecology, child health, psychiatry health, care of later life, and community-

based medicine. CP3 consists of two main components, the Advanced Clinical Experience (ACE) module and the Transition to Practice (TTP) module. ACE clinical placements rotate around partner NHS sites and comprise 32 weeks delivered in four eight-week rotations. The four rotations consist of: eight weeks of critical illness and general practice; eight weeks focused on muscles, movement and disease; eight weeks of medicine; and eight weeks of medical surgery. At the end of the module, students take the ACE knowledge and clinical examinations. Following completion of the ACE examinations, students move onto the TTP module. This begins with a career week followed by an introduction to foundational practice week. Half of the year group then proceeds onto the six-week elective periods of study, while the other half undertakes two three-week Medical Assistantship Placements shadowing of designated FY1 doctors in partner Trust sites. Each group then rotates for the final placement of TTP.

3.2.3. The Development of the CR Curriculum

The UoN CR curriculum operated on a six-step approach to curriculum development for medical education by Kern, Thomas, Howard, and Bass (1998). This six-step approach consisted of the following steps: (a) problem identification and general assessment; (b) needs assessment of targeted learners; (c) goals and objectives; (d) educational strategies; (e) implementation; and (f) evaluation and feedback (see Figure 3.2).

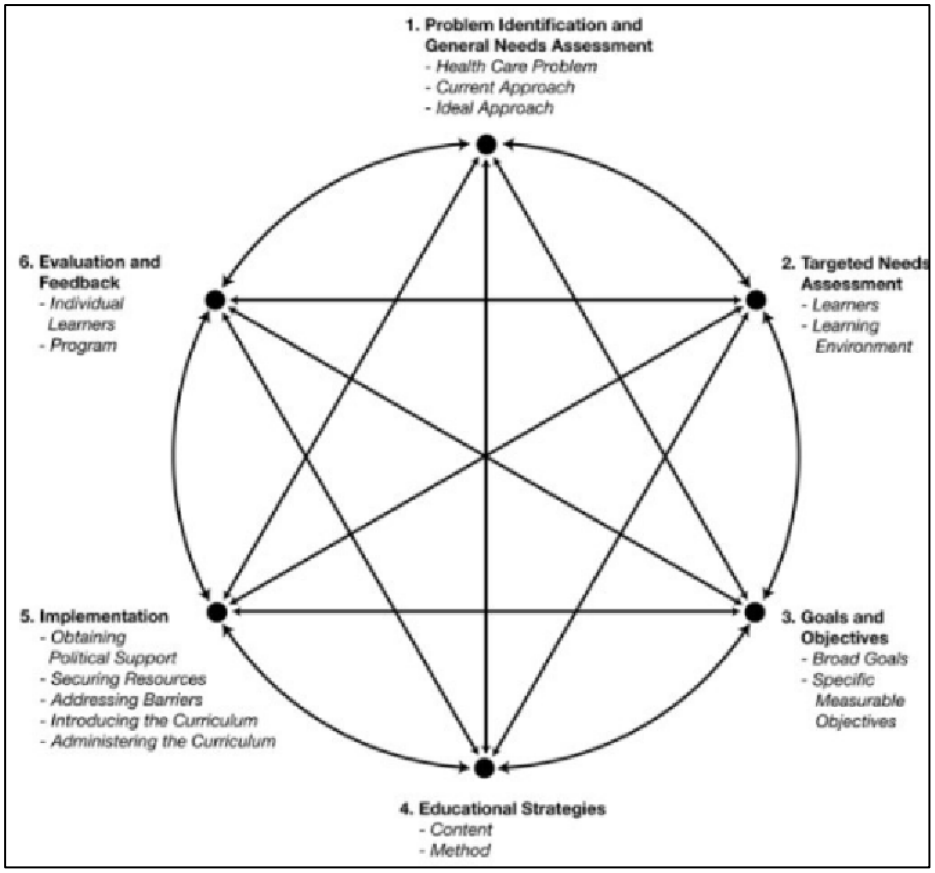


Figure 3.2. Kern et al.'s (1998) six-step approach to curriculum development.

This approach was interactive and continuous in nature and did not necessarily proceed in sequence, but was a dynamic and interactive process. Progress was often made on two or more steps simultaneously, with progress on one step influencing progress on another. The curriculum development never truly ends, as illustrated by the circle image in Figure 3.2 above. Rather the curriculum evolves, based upon evaluation results, changes in resources, changes in targeted learners, and changes in the material requiring mastery (Kern et al., 1998).

In the case of UoN, problem identification and general assessment was done by literature review. Extensive research regarding the last forty years of CR data led to the development of this CR curriculum at UoN. Chew, Zain, and Hassan (2013) stated that the curriculum development organisations and NHS are more concerned about the development of CR amongst students at every stage of their medical

educations. The curriculum has been divided into two main sections – a pre-clinical section and a clinical section. Kelly, Hager and Gallagher (2014) added that in the pre-clinical years, the students are provided with information pertaining to primary disciplines of biomedical science. However, the CR could also develop during these two years of the medical course and has not previously been emphasised. Nelson et al. (2013) contradicted this argument, stating that CR should be taught from the first year so that students would have more proficiency, applicability, and effectiveness when they are promoted to the next years of their medical education courses as well when they move on into the medical profession. Bahner et al. (2013) suggested that professors and clinicians who have different educational backgrounds should teach the students. The professors can teach the fundamental sciences, whereas clinicians could provide lectures on the practicalities of those concepts alongside their relationship with the fundamental sciences. This would result in a true integration, which is the main objective of the integrated curriculum (Bahner et al., 2013).

For needs assessment, the curriculum developers explored the current knowledge, beliefs, and attitudes of UoN medical students on CR by interviewing them. In terms of goals and objectives, the development of CR curriculum was aimed at creating or updating the standards of higher medical education and modernization of the integrated curriculum. The goals and objectives were aligned with the GMC's assertion of the importance of including learning opportunities that enable students to associate their theoretical knowledge with medical practice. It improved the existing pedagogical, educational and evaluation approaches within individual disciplines and modules. Furthermore, it also enhanced the early mastery of clinical thinking and clinical skills, the formation of scientific research skills in accordance with international standards. Educational strategies were piloted in each year and evaluated

as they moved through the curriculum in order to determine the best methods for implementation of this curriculum. After the pilot phase, the curriculum resources were formally introduced into the UG curriculum.

As for implementation, "Educational Principles that Guide the UG Curriculum" by Dennick and Garrud (2008) provided an outline of the educational principles underpinning the medical curriculum, using a curriculum framework created from a synthesis of a variety of medical educational sources. The implementation process section of the document was drawn to attention where it was noted that the politics of change are very important. Sufficient resources, political and financial support and administrative strategies need to be developed to implement a new curriculum. To this end a formal notification of change was planned as part of the School planning round. These formal notifications would meet requirements to give due notice of change that would almost certainly involve a change in resource allocation. It was noted that the scope of the curriculum review would need to be realistic, mindful of the likely fiscal pressures that would come to bear upon HE and NHS organizations.

For evaluation and feedback, Cook and West (2013) stated that a curriculum without effectiveness is a vague and purposeless content, which wastes the time and resources of learners, educators, teachers, and educational institutions. It has been noted by Cook et al. (2013) that there are certain factors through which the effectiveness of a curriculum could be determined or measured. The measurement criteria for the effectiveness of curriculum include scope and purpose of curriculum, based on valid data, developed by the well-qualified and educated people. There are many evaluation models that can be used in various learning environments. The four-level Kirkpatrick model (Kirkpatrick & Kirkpatrick, 2008) was used in this

curriculum. It has stood the test of time and stands out in terms of overall simplicity and address both summative and formative evaluation.

Level 1 of the Kirkpatrick model is the reaction. This is a measurement of the learner's feelings and opinions about the course just completed. This first level involves perceptions of the learners (i.e. staff members) who are undergoing training. Level 2 consists of the learning event and the measurements of was learned as a result of the learning event. Level 3 is the measurement of the behavioural changes that occurred as a result of the learning event. Level 4 is the results for the organisation – for example, the measurement of the overall impact of an innovation on the institutional environment. Levels 3 and 4 could not be evaluated since the students are not yet working in clinical areas and thus cannot transfer their knowledge. In the future, however, Level 3 would measure how far the trainees have changed their behaviour. Level 4 would include long-term outcomes for the organization from training.

3.3. METHODOLOGY FOR CURRICULUM IMPLEMENTATION

This section highlights the curriculum journey and how this was implemented across the UoN curriculum. The implementation in the GEM curriculum as well as CP1 and CP3 are also highlighted in this section. The section also includes details regarding the role of faculty in the implementation of the curriculum.

3.3.1. Overview of the Clinical Reasoning Curriculum Journey for Undergraduate Entry Course

Medical education is aimed at creating medical experts and includes UG education in medical schools followed by further training in residency and postgraduate medical education. Medical education and training differ widely all over

the world (Ahmed et al., 2017), with a broad spectrum of systems being used in medical education and creating a dynamic zone of educational research.

Researchers have suggested that curriculum developers should include learning content related to CR in pre-clinical classes (Papathanasiou, Tsaras, & Sarafis, 2014; Young, Cruess, Cruess, & Steinert, 2014). This means that the UG curriculum should emphasise enhancing the CR skills of students, which can help them in developing better solutions on the basis of available data regarding the conditions of patients or clients (Patterson et al., 2016; Young et al., 2014). It was agreed that the clinical case model should run through Year 1 and Year 2, in order to provide a much smoother progression and link between BMedSci and BMBS. Discussion took place regarding the best strategy to incorporate clinical cases in years one through three. Plans were made to incorporate the clinical cases used by GEM UoN students into the first two years and also to develop a special study component into Year 3 – it would be called Clinical Cases – in which students would be asked to interact with GEM-type cases.

The GEM components of the curriculum were reviewed concerning areas which might not be covered in Tomorrow Doctor's (replaced by 'Promoting Excellence', GMC). Regarding the proposed implementation of Clinical Case Scenarios (CCS), six cases were identified from PBL GEM UoN courses that mapped to many of the BMedSci Year 1's module outcomes. The committees and individual teachers made GEM cases more relevant to their existing BMedSci curriculum. Basic medical science becomes more conceptualised with clinical content. It is important to make sure the cases used within the BMedSci were not be available to GEM students as this would compromise the PBL learning approach for the latter students. It was agreed that the cases should be used in their entirety (as originally designed), and not

edited down or segmented. However, it was felt that there should be a clear indication of the lowering of importance of parts of the case that were not immediately relevant to BMedSci students at that stage. The researchers determined that each module should have a clinician involvement, presenting how the particular CCS is relevant to the BMedSci module with a summary at the end. There would be many cases that could be relevant to a module. However, since there would not be one particular module, their use could be quite limited. Using the facilitator guide obtained from the GEM course issued to staff, it would indicate how the cases might be applicable to the module so that convenors would have appropriate guidance.

Implementation of the CR curriculum CCS was planned for Year 1 and Year 2, specifically: Medical school entry in September 2011 as an on-line self-directed process. The introduction of formative questions would aid students' use of the cases and help in their understanding. Course implementation began with the Year 1 cohort school entry in September 2011 in which students had a session on the topic of 'Thinking like A Doctor" to introduce the concepts and the process of CR. In order to think like a doctor, the students were advised to learn about diseases, to learn about the things people complain about, and to merge the two. The students were informed about the logical error and bias in the learning phase and were encouraged to practice CR. This was then evaluated through a short questionnaire to see what they thought about the CR cases. Based on feedback, the case releases were redesigned for the formal group of Year 1 cohort school entry of September 2012.

Afterwards, there was an initiative to produce a revised Part I BMedSci (the first two years) that is more integrated and clinically relevant. It was confirmed that this was not a PBL programme but it was case focused. The overall aim is to produce an integrated course built on a framework of anatomical teaching, which would be

disease-focused. The level of integration would be such that teaching from the Schools of Life Science and Medicine would be fully integrated within modules. Currently, the course is divided between the School of Medicine and the School of Life Sciences and is taught in separate, themed blocks. However, we proposed to realign the course to make a much more integrated course that is patient-centred and encompasses spiral curriculum, which involves iterative revisiting topics. The intention was not to radically change what is being taught, but to re-structure around a core curriculum. The case study was used throughout the week to inform teaching and was rounded off by a case study workshop at the end of the week. This workshop was delivered by a clinician to focus on the case, responding to student-led questions. In some cases, it would be desirable to have patients brought in to discuss their conditions. Each week, therefore, would have an opportunity for optional modules or activities. A review of the GEM PBL cases was performed alongside so that there would be convergence of the two streams at the commencement of CP1. McLaughlin, Tunstall, Garrud, and Da Silva (2010) reported that they examined cases both individually and how they sat together as a body. For assessments, the direction from the GMC was to reduce the current amount, to streamline assessments, and to add more integrated papers to allow students to apply their knowledge. The proposal was to focus on end-of-year exams for both Year 1 and Year 2, with scores used for purposes of progression and BMedSci assessment.

For Year 3 of the BMedSci group, the optional module was planned to be trialed as a pilot with 24 students in three groups, an approach that was perceived as being very resource intensive. The module was designed so that students could attain some of the outcomes specified by the GMC in Tomorrow's Doctors in the areas of Doctor as Scholar and Scientist, Doctor as Practitioner, and Doctor as Professional.

Knowledge attainment and understanding specified in this module were course requirements for the students. Based on the popularity of the student preference and the introduction of new structure of the medical school, SCR optional module became mandatory for the students allocated to School of Life Sciences home bases in their Year 3. Hence, the student intake has increased to 140-150 students every year. The students were divided into 12 groups with the goal of helping students to consolidate and apply knowledge acquired in more didactic teaching. In addition, the use of clinical scenarios was an opportunity for the students to acquire skills in diagnosis and CR. Further insights on the development and implementation phases of the CR curriculum journey are highlighted in the discussion of the results.

3.3.2. Journey of CR Curriculum at GEM

In this section, the researcher describes why and how the CR curriculum on the GEM course was established. In the GEM course, CR assessments were introduced first in 2008-2009 before any formal teaching on it. Then, formal teaching was successfully implemented. The researcher was not involved in the journey of CR at the GEM site, but became the lead for CR group at the UG site and worked closely together with the GEM CR group to develop CR strand for clinical years. This information was gathered from Professor D. McLaughlin, who was the former director of UG studies at the GEM programme. This journey of assessment was explained in person, with Professor McLaughlin also providing supportive documents including CR assessment meeting notes, the proposal for the formative assessment opportunities, and his published work.

In brief, the committee and the head of Basic and Clinical Sciences determined that the students enrolling on GEM for September 2008 would undertake summative written exams at the end of their first year. They were concerned that this

might impact on “synoptic” element of the GEM assessments, so the CR summative assessments were born.

The course team also introduced students to CR formative assessments during the 2008-09 academic sessions. Each of these assessments was written by the staff from different subject disciplines. The format of the CR assessments was to model the PBL approach in which students are initially presented with limited amounts of information, with the patient story developing over three sessions. The course team determined that it would be most suitable to test students’ hypothetic-deductive skills using one-directional navigation online papers.

The new head of the school for UG studies reviewed the whole curriculum again from scratch, forming a small group of CR interest groups at GEM. However, there was no explicit CR “strand” throughout the GEM curriculum that was available to teachers and learners and mapped in the curriculum, but tested in the CR assessments. The CR interest group started developing the teaching materials for GEM students, with a few workshops for CR being delivered to the first-year students in 2016. Dr Cooper and the team published the “ABCs of CR,” established the Clinical-Reasoning.org website so that the students and the teachers could see the teaching materials, and signposted the CR syllabus in the “ABC’s of CR” (Cooper and Frain, 2016).

The following information was collected from Dr. Cooper in person and also from the Clinical-Reasoning.org website. Although work is in progress to develop an explicit CR “theme” in the pre-clinical curriculum, CR was explicitly taught through the following:

- CR workshops;
- clinical skills 'exploring symptoms' workshops; and

- evidence-based medicine lectures

Year 1:

Workshop 1: Introduction to diagnostic tests

This workshop explores some key concepts such as the probability of a disease depends on the clinical (pre-test) probability, and the sensitivity and specificity of the test (Bayes' Theorem).

Workshop 2: How doctors think

Human thinking and decision making are flawed. This workshop explores Type 1 and Type 2 thinking (dual process theory), cognitive biases and how our emotions and surroundings can affect our decision-making. 'To err is human'.

Year 2

Lecture: Human factors

This lecture recaps previous material and introduces 'human factors', 'affective biases' and some de-biasing strategies that can be useful in diagnostic decision-making (Cooper & Frain, 2016).

3.3.3. Journey of CR Curriculum for Clinical years

In this section, the researcher describes why and how the CR curriculum on the CP1 and CP3 were established. Four online CCS were delivered for CP1 and for CP3. The researcher personally created CCS and model answers based on core clinical presentations for students. These scenarios were created based on the format developed by Da Silva (2013) and formally validated as formative CR tests (CRTs).

It is increasingly normal for medical education around the globe to be supported by web-based resources, more often than not inside learning administration frameworks like learning management systems or virtual learning environments

(Kuiper, O'Donnell, Pesut, & Turrise, 2017). CRTs are theory-driven, cased-based (long case), flexible instruments that incorporate some of the characteristics of other instruments used to assess CR at the UG level. They have been used as teaching materials as well as assessment tools (De Silva, 2013). De Silva (2013) carefully designed this CRT by combining the strengths of previously developed instruments and simultaneously minimising aspects of previously developed instruments that had been criticised or had been proven to be invalid. This makes the CRT distinct from Schuwirth & van der Vleuton's (2004) approach used in studies that do not have the theoretical support structure of previous CR assessment instruments.

These are the long cases that cover all the aspects of the clinical cycle from initial presentation to diagnosis, permitting researchers to gather data on students' diagnostic performance as well as on how students perform throughout all the phases that lead to the diagnosis. The researcher picked up four core clinical presentations from the lists that all medical students should cover before they qualify for CP1 and CP3. These cases were selected on the basis of the GMC medical curriculum outcomes and the guidelines for UG medical curriculum to ensure that the difficulty level of the cases was aligned with the expected outcomes of UG medical education. For CP1, the cases were based on a condition that was highly prevalent or frequent in the context of the respondents, and/or the case presentations used correspond to a typical patient presentation for that disease so the CRT case would be expected to be easy and appropriate to their level. For CP3, the cases present less prevalent conditions or less typical presentations with increased difficulty. The clinical content of the cases was realistic and related to what students would see in daily practice and would be expected to deal with in their clinical rotations once they graduate. The next step in developing the educational resources was combining these contents into a

previously defined De Silva's (2013) CRT structure. Schuwirth and van der Vleuton (2004) said: "Question types should be selected according to their specific strengths and weaknesses." De Silva's (2013) CRT cases incorporated different question types, but the researcher used only short-answers and multiple-choice for these cases.

There were a number of reasons for these choices. Multiple question types in a test may represent a challenge to validation procedures, as the use of different types of question may lead to a decrease in the internal consistency of the instrument and hence reduce its reliability. Therefore the researcher used only two types of questions. GEM students were more used to short-answer questions, while a large majority of the assessments in the BMedSci curriculum include multiple-choice questions only. Including only one type of question could have provided an unfair advantage to the students who were more familiar with that format. Therefore the researcher used both types of questions.

Schuwirth and van der Vleuten (2004) said that there was a differential purpose for what each question was designed to assess. Short-answer questions are used to assess aspects such as summarising information, justification or reasons, predictions of results and diagnosis. Multiple-choice questions, on the other hand, are used to assess students' abilities to select between many options.

De Silva (2013) conducted a validation process of the CRT, with the results of all the validation tests showing that the CRT cases were valid and reliable tools for assessing CR. As a result, the researcher only found it necessary to repeat content validity. The researcher developed the model answers and also requested five other clinical experts to recommend what they believed to be good answers to the questions. These experts were selected from multiple backgrounds (surgery, general practice, medicine, and medical education) in order to prevent cases from being biased toward

a specific specialty. Developing the CRT was an iterative process, with experts having frequent and fundamental input into the accuracy of the clinical content in order to guarantee the content validity of this instrument before the final version.

The researcher proposed to introduce these four CRTs to UoN's CP Course Management Committee and obtained approval to put them on NLE (now Moodle). These CP1 materials were introduced to cohort 2013. The CRT was designed as an online test. Software enabled information to be made available in a sequential order, while not permitting previous answers to be modified in the face of new information.

For Screen 1, the initial presentation of the patient was described. On Screen 2, students were asked them to summarise all the patient information and list the hypothesis and appropriate course of action, along with the reason. When asked to summarize the patient information, students were reminded that, in practice, "you can't ask a patient again, and again and again to repeat"

On the next screen, students were asked to write down the questions they would like to ask the patient to gather information. The patient's answers for some of those questions were presented on Screen 4, with students required to write down the differential diagnosis. Extra information was given on the next screen to determine whether students' hypotheses had changed or not and to ask questions regarding what students expected to see in physical examination. Screen 6 provided all examination findings, asked students about their hypotheses at that stage, and inquired about the investigations they would request to confirm or exclude their hypotheses. Screen 7 showed investigation results, with students given the opportunity to decide their hypotheses again. On Screen 8, case summary and the diagnosis of the patient were presented. Students with provided with adequate space for justifying their decisions,

with questions placed at pertinent points of the clinical cycle. The CRT was useful for preparing students for clinical practice and also was a useful tool for revising exams.

3.3.4. Role of Faculty in University of Nottingham's Clinical Reasoning Curriculum

While educational techniques to improve CR skills among medical students have been developed, the lack of faculty expertise in teaching CR remains a significant barrier (Eva 2005). Teaching the teachers how to teach a subject in which they themselves did not receive formal teaching is a challenge (Trowbridge et al., 2015). This requires teachers to have new competencies and the ability to teach CR is related but somewhat independent of expertise as a diagnostician. More attention has been paid in the literature to determining the most appropriate teaching methods to be adopted by the teachers when teaching CR to their students (Ramani, Mann, Taylor, & Thampy, 2016). Lovett et al. (2016) identified the necessity for teachers who develop the next generation of clinicians with the capabilities of providing secure, high-quality health care and with enhanced capacities for reasoning, thinking, and judging.

All clinicians teach CR whether intentionally or not, but in order to ensure effective teaching, teachers need knowledge and skills that meet the evolving needs (Leslie et al, 2013; Ullian & Stritter, 1996; Wilkerson & Irby, 1998). An effective faculty development programme is critical for achieving that. In clinical years, students' clinical attachments will be varied. The development of CR depends on where they base their learning and on what learning opportunities they get. It is necessary to ensure that all teachers and learners require a common understanding of what CR is requiring the knowledge and skills that facilitate learning in this important area.

Health care professionals are obliged to systematically improve their qualifications and professional skills (Deschênes & Goudreau, 2017). The CR faculty development programme is effective in developing teaching CR skills for the clinical teachers and developing their own CR skills.

Three workshops are being run so far, all of them well-received. Fourteen clinical teachers attended Workshop 1, 30 clinical teachers attended Workshop 2, and 20 clinical teachers attended Workshop 3. The workshops are detailed below and described below.

Workshop 1 consisted of two parts, the first of which introduced CR, providing a whirlwind tour of CR to equip all of the teachers with a common language and understanding of CR. This introduction covered the different elements of CR. The second part of the workshop dealt with teaching and learning CR, focusing on what works best for learning and teaching CR. This section included a discussion of cognitive dual process theory, the factors that affect judgement and decision-making, content to be taught. Also in the second part of the workshop, the understanding of teaching and learning CR was expanded by sharing the ways that work best. Here the researcher and the faculty presented the recommendations identified previously in the literature review in light of our research findings from the students and the teachers.

Workshop 2 attempted to answer the question “How shall we change our educational practice to improve students’ clinical reasoning?” This workshop explored the recommendations identified previously in the literature on how to strengthen the teaching of clinical reasoning and student requirements during clinical attachments. The workshop also covered constraints on teaching during real-time clinical practice and how best to overcome these challenges.

Workshop 3 consisted of three parts, the forst of which answered the question "How does learning theory help us improve students' CR?" The second part of the workshop involved a small-group activity focused on the integrated SNAPPS one-minute preceptor tool. The third part consisted of a small-group activity called "Students with clinical reasoning difficulties and how we can overcome them." At the end of each workshop, participants were asked to reflect on how this material will change their practice as clinicians and as educators.

3.4. CURRICULUM EVALUATION

This section details the participant selection, instrumentation, and analysis strategies involved in achieving the goals for evaluating the curriculum.

3.4.1. Population and Sample

The target population for this study included students and teachers. Specifically, the target population included medical students involved in classes implementing at least one of the following: integrated curriculum model and PBL curriculum model. The teachers were required to be clinical instructors from the NUH NHS Trust. The researcher chose these individuals as part of the target population because the main objectives involve the overall exploration of CR as a phenomenon in students. Therefore, medical students were chosen because they are exposed to clinical settings and are expected to exhibit CR. Moreover, clinical teachers' perspectives and ideas had to be explored in order to uncover a holistic understanding of CR. Moreover, teachers and students were explicitly mentioned in the objectives of the study; thus, making them appropriate participants to this researcher.

For the qualitative portion of the study, the basis for identifying the minimum sample requirement was the point when data saturation was reached (Glaser & Strauss, 1967; Malterud, Siersma, & Guassora, 2016). Data saturation refers to the point

during data collection and analysis at which the addition of new participants or data sets does not contribute significant new information (Malterud, et al., 2016; Tran, Porcher, Tran, & Ravaud, 2017). Therefore, the number of people interviewed was not specified at the beginning of the research. Instead the sample size continued to change with the data collection until saturation was reached (Tran et al., 2017). To do this, the researcher analysed data in increments. The researcher started with analysing data from five interviews and with each addition of interview data in the analysis phase, the researcher identifies the change in number of unique codes and themes. After identifying the point of data saturation, the total numbers of participants eventually included 28 students and 11 clinical teachers. Participants included 11 final-year medical students from the integrated curriculum model, seven final year students from the PBL curriculum model, 10 third-year students from the integrated curriculum model, and 11 clinical teachers from the Trust. All these participants were interviewed from between March and December of 2015.

The researcher recruited participants based on a set of eligibility criteria (Jones et al, 2016; Kelley et al., 2014). The criteria for the selection students included requirements that students: (a) belong to either of the curriculum models of UoN; (b) be either in their final year as UG students (in order to see the effects of curricular model on the development of CR) or in their third year as UG students (in order to see how their views on CR changed or developed); and (c) be knowledgeable about the curriculum taken during the current school year. The students who were only enrolled in the third year and the final year were not considered as eligible participants of the study. For the clinical teachers, selection criteria required that they be fellows who taught clinical years at NUH NHS Trust and were familiar with and knowledgeable of the curriculum being implemented.

Maximum variation sampling strategy is one recommended strategy for purposive sampling. This could be theoretical or time- or place-based (Carter & Little, 2007; Durning et al., 2011). Durning et al. (2011) stated that a big sample size is not especially important in qualitative research; rather, it is important to reach an acceptable level of validity and information richness for selected cases and to generate observations/analytical capabilities of the research (Tran et al, 2017). The feedback from the students from Year 1, Year 2, Year 3, CP1, and CP3 were collected for evaluation process. The feedback from the teachers about their training on how to teach CR was also collected.

3.4.2. Quantitative

For the quantitative portion of this study, six cohort groups were included in the sample: 351 students from the CP1 2012 group, 344 students from the CP1 2013 group, 327 students from the CP1 2014 group, 335 students from the CP3 2015 group, 350 from the CP3 2015 group, and 318 from the CP3 2016 group. A total of 2,025 students participated in the written summative exams, a quantity deemed as providing rich data regarding their exposure to the CR curriculum in association to their clinical reasoning skills.

3.4.2.1. Data Collection

Kirkpatrick & Kirkpatrick (2008) Level 2 evaluation questions – "What has the student learned?" – was measured in this section using a quantitative research approach. The researcher requested ethical approval from the UoN to conduct this aspect of the study. However, the committee confirmed that ethics approval was not required for this kind of project since it is classed as service evaluation. Processing examination data, provided all is kept anonymous, does not directly identify people and is, therefore, routinely carried out for psychometric purposes and course

evaluation. Consultation was made with UoN Faculty of Medicine & Health Sciences Research Ethics Committee and the statement is shown in Appendix 2.

The data for this study was gathered from increasingly challenging, clinically orientated summative assessments of CP1 and CP3 written papers in different cohort years. There are between 318-351 students per cohort (see Table 3.2). The data were collected from these three years because these students had different CR teaching (see Table 3.3).

Table 3.2.
Number of Participants in CP1 and CP3 by Cohort

CP1	Students in Cohort	CP3	Students in Cohort
2012	351	2014	335
2013	344	2015	350
2014	327	2016	318

Table 3.3.
Different CR Teaching in CP1 and CP3 by Cohort

	CP1	CP3 (paper 1 and paper 2)
No CR teaching	2012	2014
Partial CR teaching	2013	2015
Full CR teaching	2014	2016

The written papers were reviewed and categorised at standard setting meetings into CR questions or non-CR questions before the exams. The total number of experts who participated in standard setting meetings varied from 15 to 25 for different cohort exams. The experts come from a wide range of specialities, including respiratory medicine, gastroenterology, cardiology, anaesthesia, emergency medicine, general medicine, orthopaedics, spinal surgery, general surgery, colorectal surgery, vascular surgery, breast surgery, and neurology. The experts serve in roles including consultants, GPs, clinical teaching fellows, medical educators, clinical skills directors, module leads, and some junior doctors. Example of CR questions can be seen in Table 3.4.

Table 3.4.
Examples of CR Questions

All of the following patients have cirrhosis of the liver. Match the clinical vignette to the appropriate diagnosis.

A. Alpha 1 anti-trypsin deficiency B. Autoimmune hepatitis C. Chronic alcoholism D. Gallstone disease E. Haemochromatosis F. Hepatitis A G. Hepatitis C	H. Hepatocellular carcinoma I. Non-alcoholic steato-hepatitis J. Pancreatic cancer K. Paracetamol overdose L. Primary biliary cirrhosis M. Primary sclerosing cholangitis N. Wilson's disease

i. A 48-year old man with new onset diabetes mellitus, two knee replacements, two hip replacements and a shoulder replacement who has a very high ferritin.
ii. A 32-year old reformed intravenous user of illicit drugs.
iii. A 58-year old woman positive for anti-mitochondrial antibodies.
iv. A 42-year old non-smoker who was diagnosed by his GP with chronic obstructive pulmonary disease (COPD) for 5 years ago.
v. A 63-year old obese, diabetic man of Indian ethnic origin. (5 marks)

The students needed to mobilise their knowledge and apply their knowledge in the clinical context to answer the questions. CR questions include content such as: (a) being given the medical history and being asked to formulate the diagnosis for each case; (b) being given physical findings and being asked to choose the most likely diagnosis; (c) being given investigation results, being asked to find a diagnosis and provide the treatment plan; (d) being given a diagnosis and being asked to choose the matching case vignette or history, and (e) being given a history, and being asked to match the investigation findings to the interpretation of the findings.

3.4.2.2. Data Analysis

Routine psychometric analysis of the medical exam was carried out for each exam paper in order to provide an assessment tool with high quality. The post examination psychometric analysis of exam data was conducted using Item Response Theory (IRT) and Classical Test Theory (CTT). CTT does not consider the interaction

between individual's ability and the test items, rather focusing on the test and its associated error (Embretson & Reise, 2000; Tavakol & Dennick, 2012). CTT considers the raw score of a test as being made up of a true score plus random error (Nafea, 2015). CTT uses methods to effectively deal with the random error, as a smaller random error leads to the test score being closer to the true score (Kline, 2005). The fundamental feature of IRT is that 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. CTT provides descriptive statistics, normal distribution, item difficulty, item discrimination for each item and the overall test reliability value. Item response theory uses Rasch modelling to provide a student-item map, joint distributions of item difficulty and student ability. By using item-student maps, problematic test items (items that are either too easy or too difficult) can be identified. Knowledge papers are analysed using test-score reliability (Cronbach's alpha), item discrimination index, and standard error of the measurement.

Frequency and discrimination (U-L) analysis and learning objective analysis were done for each paper. Item difficulty (*p*) and discrimination value (*d*) were calculated for each item. Item difficulty was obtained by the division of the number of people answering the item correctly by the total number of people answering the item. Item discrimination (*d*) was the degree to which students with high overall exam scores also got a particular item correct. Item discrimination is an index of an item's effectiveness at discriminating those who know the content from those who do not. Discrimination values were reported based on the scores. They ranged from -1.0 to 1.0. If all students answered the item correctly (item discrimination index = 0), this item did not discriminate between students. Questions with a value of less than 0.12 were unlikely to correlate well with other questions, reducing reliability. Thus, those

questions were candidates for exclusion or revision. Value was obtained by subtracting the number of students in the lower group who got the item correct from the number of students in the upper group who got the item correct, then dividing the results by the number of students in each group. The items with $p < 0.2$ (i.e. very hard) and $d < 0.15$ (i.e. low discrimination value) were marked for exclusion.

The reliability of the test was measured using generalizability (G) theory (Student× item). For tests with only one source of variation, the G coefficient was equal to alpha (Cronbach). The hope was that students' marks on the test reflected true or consistent differences between students with respect to their knowledge and skills. Because no measure is perfect, marks assigned to students on a test were assumed to include some error. G study was used to address error variance among questions. To inform decisions (D) about future measurement strategies, a D study was run.

Each test question was checked for descriptive statistics (including sample characteristics according to gender, according to the course: PBL or Integrated, students total mark distribution) and item analysis (including items discrimination, generalizability and Decision studies). The whole test was also analysed for the mean marks by case and correlation between cases. These papers were also reviewed by the external examiners and internal peers. They gave comments for some questions, with the comments being carefully considered and decisions made regarding whether action must be taken or not. The final scores were provided after these steps are taken. The tables below provide the overall results for the CPI. Overall, CR questions in CP1 written exam ranged from 73 to 116 and accounted for 46%, 39% and 59% respectively.

Table 3.5.
CP1 Marks from 2012 to 2014

	Marks			
Year	CR	NCR	Total	CR % of total
2012	85	101	186	46
2013	73	112	185	39
2014	116	79	195	59

CR questions in CP3 written exam ranged from 85 to 151, accounting for 50%-79%.

Table 3.6.
CP3 Marks for Paper 1 and Paper 2 from 2014 through 2016

	Paper 1 Marks				Paper 2 Marks			
Year	CR	NCR	Total	CR % of total	CR	NCR	Total	CR % of total
2014	151	41	192	79	87	83	170	51
2015	85	85	170	50	91	79	170	54
2016	113	57	170	66	98	77	175	56

Mean comparisons were conducted if significant differences were observed. ANOVAs were conducted to determine whether there were significant differences in the CR scores and total scores of the summative written exam across the categories of the independent variables of frequencies of participation of CCS (0 to 4) and CR teaching implementation (none, partial, or full CR teaching). This analysis determined whether participation of CCS CR teaching (RQ1) had a significant effect on the course outcomes measure. Post-hoc tests using Tukey's test were conducted if significant differences were observed to further examine the effects of the independent variables on the dependent variable. A level of significance of 0.05 was used in the analysis. This section of the study presents the summaries of the data

analysis using descriptive statistics, independent sample *t*-test, and ANOVA. IBM© SPSS® Statistics Version 22 was used to conduct the data analysis.

3.4.3. Qualitative

The researcher acted as the data collector, the selector of the relevant data, and the caller of meaning emerging from data. Althought data was often described in the participants' own words, data interpretation could still reflect the specific stance and thoughts of the researcher. Therefore, a transcript was sent to the interviewees to keep a record of what had been said and to provide opportunities for them to validate the information and add further information. The researcher met with participants face-to-face, explained the aim of the research, and provided copies of the volunteer's information sheet (see Appendix 1) and an informed consent form. The informed consent form included details of the background of the study, provided reasons for participants' selection, described what they would have to do, and articulated what would happen to the results. The researcher described the study purposes and strategies and explained the optional nature of participation. Participants were informed that their confidentiality would be maintained by removing any personal identification obtained during the interviews. Those who agreed to the contents of the consent form were asked to sign and return a copy to the researcher. Communication between the participants and researcher was then carried out through email to arrange for interviewing.

3.4.3.1. Questionnaire

Open-ended questionnaires with follow-up questions were used in this research since there were no standard expected answers to the questions. Moreover, open-ended questions enabled the researcher to gather more information from the participants. Questions were formatted to be open-ended in order to encourage the

participant to elaborate. The questions in the interview guide were subjected to an expert review for validation purposes. The experts included two members of the dissertation committee and one expert in the field of CR. Each expert had at least 10 years of experience in his or her respective field. The experts assessed the appropriateness of the word usage, structure, and content of each sentence in the interview guide. The words included in the interviews were appropriate for its intended users, such as the researcher and the participants. The experts also ensured that the items in the interview guide are appropriate to allow the research to achieve the objectives. Based on the emergent and prominent comments from the expert review, the researcher made changes to the questions in the interview guide.

A set of final six questions was determined to deeply address the understanding of CR skills by the participants, their personal experience of this phenomenon, and their learning experience of CR. The six questions were as follows:

1. What do you understand by CR?
2. Why is CR so important?
3. Did you notice any difference in PBL curricular model group's CR and the integrated curricular group?
4. Are there any formal learning opportunities you have to develop your CR and what do you think about learning/teaching CR?
5. How do the students learn/ develop CR and how could we emphasise CR more?
6. Do you think that we assess CR in your exams?

To assess the pilot implementation of the CR curriculum, the researcher designed a short questionnaire provided on-line to seek the students' opinions on the CR cases that were made available. This evaluation was performed to address the

students' perceptions of the value of the CR training experience. The questionnaires begin with a series of closed questions that measured the students' ratings of the sessions and ended with open questions to seek the students' detailed opinions and insights.

3.4.3.2. Interviews

For qualitative study, interviews are one of the most commonly chosen instruments used for collecting data, as they allow for in-depth data gathering (Brinkmann, 2014; Kallio, Pietilä, Johnson, & Kangasniemi, 2016). As the study aimed to get a deep understanding of CR among the students, the qualitative interview method suited the purpose of the current study. The most common types of interview are unstructured, semi-structured and structured interview (Kallio et al., 2014; Robinson, 2014). In semi-structured interviews, the researcher seeks to collect specific information that can be compared and contrasted with information gained in other interviews. A semi-structured interview met the needs of the current study; thus, an interview schedule was designed with a list of topics to be discussed. Through semi-structured interviews, the researcher was able to ask follow-up questions and encourage participants to provide details about their perceptions about CR, while remaining aligned with the topic and objectives of the study (Kallio et al., 2014; Robinson, 2014).

The researcher also asked the same questions of the clinical teachers in order to check the teachers' understanding of CR, to determine how they have acquired and taught it, and to ask about how they could better incorporate CR teaching and learning in their own teaching. The results from the qualitative interviews were then used in two ways: (a) results were used before the course to understand teachers' and students'

perceptions of the different aspects of CR; and (b) results were used in learning needs analysis, specifically as a starting point for developing CR curriculum.

The interviews were conducted in quite places, the researcher's office, small seminar room at UoN. All interviews were audio-recorded for easier transcription. The researcher was responsible for interviewing the participants and recording these interviews using an audio digital recorder. An interview schedule was constructed. When the interviewee raised new pertinent issues, these could be added to the schedule for the next interview. A professional transcriptionist, Kath's Keying Service, was hired to transcribe the interviews, with the transcriptionist being required to sign a non-disclosure agreement. The researcher checked the transcripts against the original audio recordings multiple times, adding data to the transcripts as necessary. Reading the transcripts many times before the coding began also helped the researcher to become familiar with all aspects of the data and to suggest possible patterns.

3.4.3.3. Data Analysis

The pragmatic method offers an outcome-oriented and practical method of inquiry that allows researchers to select methodological approaches in a way that can best answer their research questions. It also endorses a practical empiricism as the best way to determine what works. The pragmatic approach to data analysis is best suited for mixed-method research because it has the potential to reduce some of the problems associated with singular methods by incorporating the strengths of both quantitative and qualitative methodologies (Burke Johnson et al., 2004).

Thematic analysis is a highly qualitative, reflective, and highly inductive type of analysis that applies emerging themes to the entire data (Darlington & Scott, 2002). Inductive thematic 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 (Nafea, 2015). The researcher conducted inductive thematic data analysis for this study. Green and Thorogood (2009) noted that qualitative analysis of data depends on imagination and the ability to make links, together with the knowledge base to draw upon. However, it should be rigorous and reflective of the links between the collected data (Green et al., 2009).

Data was analysed as the research progressed, with the researcher working to continually refine and organize data in light of the emergent results, as described by DiCicco-Bloom and Crabtree (2006). It is ideal to get more understanding of the interview questions by the researcher and informs both future questions, sampling and also inform when data saturation is reached (DiCicco-Bloom et al., 2006). 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, Vinz, Downing, & Anzul, 1997). Themes were agreed upon with the researcher's mentor or supervisor. As suggested by Green et al. (2009), it is always advisable to agree upon coding themes and their meanings with supervisor if the researcher is not working in a team.

In reporting the results, each participating student was identified by code and a number. The identifying code represented the student's phase and group, while the number referred to student's order in which he/she was interviewed. CP3 I1, for example, denoted the first interviewee from the integrated curriculum from CP3 (final year).

The evaluation of the CR curriculum was conducted using Kirkpatrick & Kirkpatrick, 2008) four-level model. The four levels are: reaction; learning; behaviour, and results. The researcher collected information about the reaction to the learning event (Level 1) through questionnaires. Level 2 data was collected by measuring what

students had learned through analysis of their exam performances. Level 3 and Level 4 could not be evaluated at present, because the students are not yet working in clinical areas and thus cannot transfer their knowledge. In the future, however, Level 3 would measure how much trainees changed their behaviour and Level 4 would include long-term outcomes for the organization as a result of training. Thus, this research focused on evaluating the learning event by using the first two levels of Kirkpatrick model. What the students felt about the learning event (Level 1) was measured using the results of the pilot evaluations, with the results being analysed by a student representative and presented by the same student in the committee's feedback meeting. The results of this evaluation were then used to improve or redesign the curriculum for succeeding implementations.

The learning event effectiveness among the teachers was also measured by reaction of the participants to questions about whether they felt that the training was a valuable experience or not and whether it measured what they learned. After delivering each and every workshop for teachers on teaching CR, feedback forms were collected consisting of a questionnaire in regard to their perceived effectiveness of the CR training workshops. This information was also used as post-learning event evaluation.

3.5. THREATS TO VALIDITY AND TRUSTWORTHINESS

In qualitative research, validity, reliability, and objectivity may be replaced by the terms credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). To improve credibility, the researcher performed member checking. The researcher also conducted an expert review in order to improve credibility of the data. To improve transferability, the researcher provided a detailed discussion of the procedures done during recruitment, data collection, and data analysis. To improve

dependability, the researcher presented the findings with extensive detail and provided appendix that contains relevant documents used for this study. Finally, to improve confirmability, the researcher ensured that data was collected and analysed in an objective manner by having a member check and transcribing the interviews verbatim to avoid changing the actual data that was obtained from participants.

There are other techniques to improve validity and reliability of qualitative research, including the method of respondent validation or member checking used in the current study. 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). The codes for this study were by a colleague currently carrying out research another aspect of CR. According to Green and Thorogood (2004), credibility of qualitative research is supported by presenting 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 et al., 2009).

Because the researcher is a human being, error and personal biases have the potential to influence the findings of the study (Smith & Noble, 2014). Moreover, the long period of time spent on research about the topic of this research have contributed to the preferences, beliefs, and knowledge of the researcher about the topic. The researcher's personal expectations have also been influenced because of the developed preferences and personal biases. To prevent having personal biases as significant influencers when conducting interviews and analysing of the data, the researcher acknowledged and listed any personal expectations, experiences, and opinions that were related to the topic of the study. Through this process, the

researcher became more aware and careful when drawing interpretations and conclusions from the data.

Another threat to the validity of the study was the use of purposive sampling, which does not assume random selection of participants and normal distribution of sample data (Palinkas et al., 2015). Although the data collection was carried out at only one trust in order to save the travel time and administration time, the university ensured that all the students received a fair and balanced allocation to gain educational experience at both large teaching hospitals and other partnership trusts and help to build resilience. An accessible sample was used in purposive sampling, while bearing in mind that the students at NUH NHS trust are believed to represent the whole cohort.

For the quantitative portion of the study, both CP1 students and CP3 students sat OSCEs together with these summative written exams. The researcher could not analyse their OSCE performance, placing a richer more complete dataset out of reach. However, the researcher obtained sufficient data to test the research questions posed and determine the effect of gender on exam scores.

As noted in Chapter 2, there is no gold standard for the assessment of CR. It can be assessed by using multiple episodes, by employing a variety of tools, by examining multiple contexts, and by making multisource assessments both in exam settings and in the workplace. The data in this quantitative chapter uses purely summative knowledge papers as a proxy measure. All the different aspects of CR could not be assessed. However, the knowledge papers of all the summative clinical exams included the question types including: extended matching, multiple responses, multiple-choices, labelling, matrix, image hotspot, calculations, and ranking. Some of these tests are known to assess knowledge as well as CR and diagnostic reasoning.

3.6. ETHICAL PROCEDURES

With research that uses human beings as data sources, ethical issues must be thoroughly addressed in order to protect the rights of these participants. As part of ensuring that the participants were provided with ethical considerations, every participant was asked to read and sign an informed consent. Only those who agreed with the contents of the consent forms were asked to sign the document and were then selected for participation in the study.

Another ethical consideration was the voluntary nature of participation. Those who decided to participate were notified that they were freed from any consequences for their decision. Those who wanted to terminate their participation in the middle of data collection were allowed to do so, without incurring any consequences. In the same manner, no incentives were given to those who participated in this study.

Another ethical consideration was participant confidentiality. The names or identity of the participants were kept confidential. The researcher used codes to replace the names of the participants. These codes were used in all the data sheets. When reporting the answers and findings, the researcher also used codes that correspond to each participant, when needed. The final ethical consideration for the study was data security. To secure the data, the researcher kept all data files in a locked cabinet to which only the researcher had access. Moreover, data files will be kept inside the locked cabinet for five years after finishing this study. After five years, the data files will be burned and destroyed.

3.7. SUMMARY

This chapter included a discussion of UoN's clinical reasoning curricula through a review of the university's educational resources. UoN has also begun its efforts toward introducing CR-oriented curricula among their UG students. The

section also discussed the methodology for development, implementation, and evaluation.

CHAPTER 4 RESULTS OF THE STUDY

This chapter contains the results of the study. In the first section, the researcher presents the implementation of the CR curriculum, describing its final structure and organisation. In the second section, the researcher presents the qualitative results. The third section outlines the quantitative results of this mixed-method study.

4.1. A DESCRIPTION OF THE CURRICULUM

Despite the importance given to CR in universities globally, studies have shown that CR continues to be taught explicitly only to a small extent. A review of existing literature similarly revealed a lack of studies regarding the implementation of CR courses in undergraduate medical training (Harendza et al., 2017). The research problem that the study sought to address was the lack of knowledge regarding the development of CR and CR awareness among students in the undergraduate level. Although the term CR is widely used in most medical and dental curriculum documentation, it is rather a complex process, particularly in terms of understanding its meaning and and in terms of formulating specific evaluation tools (Norman, 2005; Higgs et al., 2008). The main focus of this mixed methods study was to develop, implement and evaluate how CR is being integrated into the UoN curriculum for the UG medical degree. The study also addressed the gap in the literature in regard to the impact of different curriculum designs to how students learn and develop clinical reasoning skills.

In this study, the researcher was involved in all the steps of the curriculum design process as part of the curriculum committee. The piloted design was evaluated for effectiveness in improving the knowledge of the students through increasingly challenging summative tests. Evaluating whether CR was embedded into the

curriculum was a key part of this study. One of the principles of curriculum evaluation involves gathering data on what is occurring in the curriculum. Curriculum effectiveness can be measured via student and staff feedback questionnaires and also their performance in the summative exams.

Finally, CP1 and CP3 summative knowledge paper questions were reviewed by experts who identified the questions with CR components. By comparing the results of those questions in summative knowledge-based exams, an attempt was made to measure the effectiveness of the new CR curriculum in developing CR skills and to explore the effects of the different curriculum models as well as the effects of curricular phase of the curriculum and gender on CR. In addition, the results of the summative knowledge-based exams were supplemented by interviews with students and teachers.

The primary focus of the study was to answer the question, “How is CR being embedded in the UG University of Nottingham CR curriculum?” To that end, background information on the implementation of CR was developed. This involved monitoring all of the planning processes and implementation decisions and devising evaluation tools to measure how effectively the curriculum elements achieve their goals. This study followed a moving target, with identification of areas where CR curriculum is being developed and implemented being a key part of the study.

Brauer and Ferguson (2015) stated that the first two years, which are considered as the pre-clinical years, have a great importance in the medical curriculum because they address numerous areas that have relevance to CR and to medical profession. Therefore, the development of CR should be supported through the provision of a vast knowledge of clinical concepts and basic medical sciences in the pre-clinical years.

The UoN pre-clinical course, BMedSci, becomes more of an integrated course with more clinically relevant experience, case studies, and a patient-centred approach, along with an increased focus on dissection studies. The change was not a content change necessarily, but a re-ordering and re-badging according to each weekly theme or case. The science component of the BMedSci was not dropped, but was reinforced by an increase in the CR activity. Implementation began in September 2017. As of 03,2019, the GEM course with its CR components was still continuing. CR has been implemented successfully for the clinical years and in a faculty development programme for clinical teachers. These key concepts form the CR curriculum and, therefore, must be considered when measuring the effectiveness of the curriculum. Appendix 4 contains the final CR curriculum document for the students, showing how CR was embedded and how it was linked to the existing programme. The document attached in Appendix 4 also contains the vertical curriculum and the elements in the CR, including which element is teaching implicit CR in the final CR curriculum model shows that CR is successfully embedded.

4.2. QUALITATIVE RESULTS

4.2.1. Student Evaluations and Feedback Meeting

The results of the pilot evaluation through the short questionnaires provided to the NLE in regard to the CR cases during the pilot implementation showed that for Year 1, 87 of 248 students (35%) completed the online questionnaire, with 42 students completing the free-text portions of the questionnaire. Findings showed that 13 of 248 students (5%) acknowledged the relevance of CCS to their modules and career. In addition, no other issues were raised during the feedback meeting as none of the issues presented in the questionnaire were encountered by more than 5% of the sample, which was the threshold assigned by the committee.

Curriculum effectiveness was also measured through the student feedback questionnaires in Year 2. Out of 252 students, 125 (50%) completed the online questionnaire, with 154 students completing the free-text portions. The results showed that 44 out of 116 students (38%) agreed and strongly agreed to the usefulness of the CCS module in supporting the clinical laboratory sciences. Moreover, 70% of the students agreed or strongly agreed that the clinical contents of the cases were realistic and related to what is expected in practice, 49% agreed or strongly agreed that the CR tests helped developed their CR skills and data interpretation skills, and 48% expressed their desire for more CR tests and emphasized this in their free-text responses as well. Samples responses are presented below.

- *"I think these types of learning aids are very useful, therefore more cases and increasing variety would be extremely beneficial."*
- *"I think it has a lot of practical value as well as a sort of academic value: helping you prepare for potential cases in the knowledge papers and for my future career as a doctor to be able to think in a structured way."*

Some students would also like to have individual and more detailed feedback, written resources, more cases linking to the modules that they are covering and send more reminders about these cases using text messages. Samples of those responses include those listed below.

- *"You don't get very many and then so a lot of people forget to do it. Rather than they don't want to do it but you'd do one a week or something so it was just always in your head that, 'I've got to do that before Friday'."*
- *"I do find them very useful. I think sometimes it's very difficult because if you're presented with a case that you haven't yet done a reading about. You don't quite get the full benefit from it"*

- Year 1 students stated, "*Unlike first term I really felt that I was being reminded of why I was at Medical School. It really boosted my confidence and interest for the course and encouraged me that there was light at the end of the dark tunnel of first term*!!"
- In year 2 feedback, more than 50% of year 1 students stated, "*the CCS stimulated my interest in clinical medicine*."
- Year 3 students said, "*Great module. Very interesting and relevant to medicine! It helped me build my teamwork skills and I learnt a lot about problem solving and the process of diagnosing and treating a patient*."
- CP1 students mentioned, *"Well I've really enjoyed them because that's exactly what you come across when you meet someone on the ward, and as you work through ---those CR assessments --- at a very smooth way where you can sit down and work through as if they were a real patient. So, I find that quite useful."*
- CP3 students added, "*They're good because they go through the steps and help you to --- go through the process yourself and see what is happening and make some decisions based on the information that you've got. So that reflects what happens in real life."*
- The GEM students' view on new assessments was very positive too. For example, '*I like the reasoning exams. I think they are a good idea conceptually. I believe that most modern-day exams may be prepared for in the majority by pure memorisation and I do not like this fact. As doctors we will need knowledge, which will have to be memorised, but the use of the knowledge, through reason will be as important as the knowledge itself.'*

4.2.2. Teachers' Learning Needs Assessments and Evaluations

After the implementation of the training workshops, feedback forms were collected for post-learning event evaluation. All of the attendees rated the workshops with a score of 4 on a 5-point Likert scale. Some of their feedback included appreciation for the very interactive session from credible tutors, excellence of the sessions, great learning experience, fantastic examples and resources, interesting sessions, multidisciplinary approach, thought-provoking approach, and challenging thoughts and ideas presented. They also stated that the things they found most useful were the tips and techniques on teaching CR, the elements that can be used to improve CR teaching, the increased understanding of the different typed of biases through case-based discussions, excellent background to CR, evidence-based CR, good whistle-stop tour, dual process theory, and the reminder of problem list. The TFs and nurse educators found the trainings to be useful and stated that it would change their practice as clinicians and educators. Samples responses included those listed below.

- *"Puts theory behind some of our existing practice and suggested new ideas to expand our teaching practice"*
- *"Cemented a lot of my previous knowledge"*
- *"It made me think about how I think and de-biasing strategies and cognitive forcing strategies to promote safety"*
- *"Gave me new ideas to discuss CR process with learners in every educational intervention"*
- *"Fundamentals of CR how I can put into practice and will change my practice"*

Health care professionals are obliged to systematically improve their qualifications and professional level (Deschênes & Goudreau, 2017). The CR faculty

development programme was effective in developing teaching CR skills for the clinical teachers and was effective in improving their own CR skills and should, therefore, continue to run every year. The suggestions to move forward is expand this faculty training to wider audience from different NHS trusts and for the non-clinical academic teaching staff. Clinical teachers rotate every two years, requiring careful planning to ensure that both the new teachers and who have already attended this session benefit from that.

The pre-course and learning needs assessments interviews with the trainers showed that almost all the fellows supposed that CR needed to be taught but they were not sure whether it could be taught or not, how to teach and when to teach.

- *"I don't think you can teach it so that people are expert in their CR at the end of medical school. I think it's more about giving them some insight into what they're doing, how they're doing it"*
- *"How we teach it. I'm not quite sure if there are specific models that are taught to them. I don't know."*
- *"I think it's a theme that needs to be- it's not going to be a totally natural process for anybody. So, something needs to happen to support it. So, it's not a thing I've put a great deal of thought to which is terrible really."*

Some barriers to teaching CR were also discussed. Some respondents stated that it is very difficult subject to teach because firstly, domain-specific knowledge is essential. The scope of CR is also vast, complicated, complex, and context-specific. Moreover, it is developed through experiential learning, deliberate practice, and expert performance. This results in teachers' uncertainty with teaching CR, as shown in sample responses below.

- *"The students are exposed to a lot of things very, very early--- they have no idea of the significance… They should have a degree of knowledge that would be appropriate."*
- *"Well I think CR has to be specific to a patient. I think it's very difficult to do generic CR. I think it's got to be, 'This is the situation. How do you reach that decision on this patient in front of you?' which I guess would bring challenges to the teaching side."*
- *"I think it is an aspect of continuing professional development which should continue to develop even when you're a consultant. So, I don't think you can teach it so that people are expert in their CR."*

Participants also mentioned the factors that influence the development of students' CR. Such development depends on where they based and what learning opportunities they get. It also depends on the clinical phase and on the curriculum model of students. Moreover, in order to get the consistency between all different sites, training the teachers on how to teach CR in clinical settings is recommended. It is necessary to ensure that all the clinical teachers from different sites have the competencies to teach these skills. More than half of the clinical teachers supposed that CR was not specifically taught at UoN.

- *"There's very little consistency or methods for consistency that I can see between all the different sites."*
- *"I've not personally observed any teaching on this concept."*

In the following sections, the emergent themes from the interviews with the different student and teacher groups are described. This is followed by detailed analysis and comparison of the samples and by a final discussion of each individual major topic area.

4.2.3. Understanding and Meaning of CR

The answers of the students to the question "What do you understand by CR?" are presented below. All of the students were familiar with the term CR, but were uncertain about its various components. The five themes generated from this question are summarized in Table 4.1.

Table 4.1.
Themes for the Category of Understanding and Reasoning

Themes
1. CR is a cognitive process in a way of taking a problem, gathering the information and then formulating a differential diagnosis.
2. Some expanded the outcome of CR from formulating a differential diagnosis to include the investigation and treatment plan to cover all aspects of the clinical cycle.
3. Some added applying/combining the information with the knowledge and experience to do reasoning.
4. Some broke down complex multifactorial processes that take place during reasoning.
5. CR is context-dependent.

The answers given for this question are summarized as follows:

a) CR is a cognitive process in a way of taking a problem, gathering the information and then formulating a differential diagnosis.

- *"It's just working out a potential diagnosis from the information you've been given." (CP1 4)*

b) Some expanded the outcome of CR from formulating a differential diagnosis to include the investigation and treatment plan to cover all aspects of the clinical cycle.

- *"A process of acquiring information logically— either rule out or rule in clinical diagnosis, investigations, manage the patient— is your treatment working?" (CP3 I 3)*

c) Some added applying/combining the information with the knowledge and experience to do reasoning.

- *"It's the ability to assimilate information given— history, examination, investigation, findings, and then to process and formulate a differential diagnosis and then create a management plan based on your knowledge and experience." (CP3 P 5)*

d) Some broke down complex multifactorial process, that take place during reasoning

- *"It is about appropriate questioning of ruling in and ruling out pathologies— is actually looking and thinking and using pattern recognition." (CP3 P 6)*

e) Others emphasized that CR is context-dependent

- *"Use a logical process to understand the situation which will then help you with— diagnosis and the management and what investigations to perform." (CP1 10)*

CP1 students defined CR as linking together all the information, knowledge, and experience and expanding the product of CR from formulating differential diagnosis to including the management plan. However, three of the ten CP1 students (30%) considered a context-dependent way of thinking and decision-making. Some CP3 students defined CR as taking all the information and coming up with differential diagnosis and expanded this to include the management plan that involved investigations, treatment and some steps of the clinical cycle and also added applying information derived from knowledge and looking at the big picture. They also mentioned the sub-process of CR. Responses included those listed below.

- *"It's the ability to use past experience— to be able to link together— in one coherent bit." (CP1 5)*
- *"Using your Clinical judgement and the previous knowledge— to make logical decisions." (CP3 I 6)*
- *"Pathway of your thought— start with differentials and then you rule some out or include some— (and) treat a patient safely." (CP3 8)*

CP3 PBL students defined CR from formulating differential diagnosis to the management plan that involve in all the clinical cycle and also added applying/combining the information they gathered with their pre-existing knowledge. They also defined CR with many components such as the sub-processes and a context-dependent way of thinking. Students also mentioned that CR does not end with diagnosis and patient-centred EBM and shared decision-making are important elements of CR.

- *"Thinking about what you would do in terms of a history, examination, investigations and— find a diagnosis and manage it accordingly." (CP3 P 2)*
- *"Thought process that leads you to the diagnosis or— informs your choice of— tests to help rule in, rule out, likely conditions. It is constantly shifting with reference to the new information that you get." (CP3 P 1)*
- *"Both verbal and non-verbal sort of cues which can ---feed into your CR --- there's a lot that's not said but— use what you're seeing as well as what you're hearing, that all feeds into— reasoning for a case." (CP3 P 3)*
- "*Using best clinical practice by evidence-based medicine as well— [National Institute for Health and Care Excellence] guidelines and Trust*

guidelines, and using that as part of your reasoning to direct— care plans." *(CP3 P 7).*

The answers of the teachers to the question "What do you understand by CR?" are presented below. The five themes generated from this question are summarized in Table 4.2.

Table 4.2.
Themes for the Category of Understanding and Meaning of CR (Teachers)

Themes
1. Most participants affirmed that CR is a cognitive process, that underlies decision-making and, in this context, to diagnosing practitioners in healthcare.
2. Some teachers expanded outcome of CR from formulating differential diagnosis to the management plan. Some added the fact that CR is combining the information they have already gathered with what they know in theory and justify the clinical actions.
3. The process that takes place during reasoning: generating hypotheses, testing, assessment and evaluation of risks/benefits and judgements.
4. Others emphasized CR is a context-dependent and needs situation awareness.
5. Metacognition has to be considered as part of CR to improve decision-making.

The answers for this question are summarized below.

a) Most participants affirmed that CR is a cognitive process, that underlies decision-making and, in this context, to diagnosing practitioners in healthcare.

- *"CR is the ability of a— healthcare professional— to make decisions based on the information— and come to a sensible differential diagnosis."* (TF 7)

b) Some teachers expanded outcome of CR from formulating differential diagnosis to the management plan. Some added the fact that CR is

combining the information they have already gathered with what they know in theory and justify the clinical actions.

a) *"How you come to the decision you do— how you apply the theory— to that particular patient in front of you because the decisions for particular patients are— more complicated than the theory in a textbook."* (TF 4)

c) A minority of the fellows stated the process that takes place during reasoning: generating hypotheses, testing, assessment and evaluation of risks/benefits and judgements.

- *"Dealing with— the most likely diagnosis, what you think the other important diagnoses are, and honing that down— saying it's this diagnosis."* (TF 4)

d) Others emphasized CR is a context-dependent and needs situation awareness.

- *"One of the areas— have neglected is— situational awareness— to interpret the situation that the patient's in— and making that decision."* (TF 7)

e) In addition to all of the above, TFs emphasised that metacognition has to be considered as part of CR to improve decision-making.

- "*We can't produce doctors who do not have metacognition in CR."* (TF 2)

4.2.4. Importance of CR

The answers of the students to the question "Why is CR important?" are presented below. All participants acknowledged that CR was very important for them. Three themes were generated from this question and are summarized in Table 4.3.

Table 4.3.
Themes for the Category of Importance of CR (Students)

Themes
1. CR is the fundamental skill for the healthcare practitioner and needed to be used every day.
2. CR is important to be an efficient clinician
3. CR is important to provide the best care of the patient.

The answers for this question are summarized as follows:

a) CR is the fundamental skill for the healthcare practitioner and needed to be used every day.

- *"It's a skill more than anything to be able to do— as a clinician."* (CP1 9)

b) CR is important to be an efficient clinician.

- *"You're going to be seeing a large number of patients. You need to be efficient you can do all the good histories— just following the Calgary-Cambridge Framework, but if you're not actually focusing in on questions that are relevant for each patient, — (you don't know) what is going on."* (CP3 I 10)

c) CR is important to provide the best care of the patient.

- *"It gives you a good foundation for why— to follow good medical practice— the guidelines and the best treatment options for that patient to give the best care and— applying ethical principles, etcetera— reasoning helps to focus that to the most appropriate treatment for that specific patient."* (CP3 P 7)

All the CP1 students admitted that CR was what they would apply throughout their lives. Only one student, however, mentioned its importance for treating the patient properly.

- *"The foundation for making proper clinical decisions and treating patients properly."* (CP1 10)

All CP3 integrated curriculum students said that CR is a basic part of the future everyday job and believed that they could not work in real life without the CR skills. They accepted that CR is paramount to being an effective doctor and for the best care of the patient.

- *"You've got all the knowledge in the world— but when you're on the ward, that's not what you need. You need to have— CR skills but (if you) don't have (it) well it's completely pointless having the knowledge because you can't use it."* (CP3 I 4)
- *"Adaptability's quite a big thing about it because each patient— present differently, different symptoms, and it's— the functional use of that knowledge— to kind of best care for people and help you be an effective doctor."* (CP3 I 8)

CP3 PBL students stated that CR is important because it's essential to who doctors are and what they do.

- *"It's— what a doctor does really."* (CP3 P 4)
- *"Otherwise, a computer could do your job."* (CP3 P 6)
- *"You need good CR to save time and save resource."* (CP3 P 1)

The answers of the teachers to the question "Why is CR important?" are presented below. Two themes were generated from this question and are summarized in Table 4.4.

Table 4.4.
Themes for the Category of Importance of CR (Teachers)

Themes
1. Clinical teachers thought that CR was very important only because it was

the main function of a doctor. 2. Other fellows also acknowledged that CR is important to get a correct diagnosis and to avoid over investigation and treatment.

The answers for this question are summarized are sampled below. Of the clinical teachers interviewed, 55% indicated their beliefs that CR was very important because it was the main function of a doctor. TF 1 mentioned the words "prevent errors" explicitly, but other fellows also acknowledged that CR is important to get a correct diagnosis and to avoid over investigation and treatment.

- *"How you do your job. You build your tree of knowledge but then it is picking up which parts of that tree are really important. There are lots of causes (for that symptom), but what makes you think that this is a particular cause versus another. That's basically what you do day-to-day as a doctor"* (TF 3)
- *"Plenty of doctors— have extremely good knowledge and extremely poor CR. You can ask them about the evidence base and they can quote studies, (but) when it comes to applying— they struggle and can lead to over-investigation, can lead to over-treatment."* (TF 4)

4.2.5. Differences in Learning

Students answers to the question "Do you notice any difference in the CR from PBL students and integrated students?" are presented below. All participants acknowledged that CR is very important for them. Four themes were generated from this question and are summarized in Table 4.5.

Table 4.5.
Themes for the Category of Differences in Learning (Students)

Themes
1. All fifth-year integrated students believed that PBL students are better in CR.
2. Almost all fifth year PBL students agreed that their CR is better.
3. Half of the third-year integrated students said that PBL students have better knowledge and applying it
4. All CP3 groups uniformly accepted that there was no discrepancy at all at different points like at the end of CP1 or at the entry of CP3 or during CP3.

The answers for this question are summarized below.

a) All fifth-year integrated students believed that PBL students are better in CR.

- *"I think in that respect their knowledge is probably slightly better. Like coming up with differentials and things like that, they were a lot quicker. I remember on CP1 thinking some of the words they were using, I'd never heard them before, but as I read, then they were coming to me."* (CP3 I 11)

b) Almost all fifth year PBL students agreed that their CR is better.

- *"The knowledge of basic pathology and how it presents is not there really in a lot of cases. So, they're very scientific and have very little clinical, which I found quite surprising."* (CP3 P 6)

c) Half of the third-year integrated students said that PBL students have better knowledge and applying it.

- *"I think they seem to sort of be able to do it better. I'm not sure if they've done more of it in the past because I don't know how it works."* (CP1 6).

d) All CP3 groups uniformly accepted that there was no discrepancy at all at different points like at the end of CP1 or at the entry of CP3 or during CP3.

- *"By the end we were much a par with each other. I think it didn't actually take that long to be honest. So, I think it was only a couple of months— you couldn't tell anymore. I think we were all at a similar level then."* (CP3 I 10)

The reason for this difference might not necessarily because of the curricular model but also because of the other factors. The other emergent themes included confidence, timing, motivation, background, and life experience.

- *"I think they've got the confidence to just keep attempting, whereas we're more shy maybe."* (CP1 3)
- *"I think part of it was because we'd (PBL) come straight from exams. So, we were already sort of primed and sort of in running mode, whereas they'd (integrated) had like a few weeks off— and their projects. So, they'd just come back from a break."* (CP3 P 3)
- *"They wanted it a lot more, you know, you're a GEM (PBL) student. You've gone through a lot more to get into medical school in the first place and I think they worked a lot harder than we did to make themselves ready for CP1."* (CP3 I 9)
- *"I've been a paramedic for many years before being a medical student. So, I've— an amount of clinical acumen before (and) some CR and this has sort of added to it."* (CP3 P 6)
- *"Their experience of talking to patients is not as good as the GEMs (PBL) I would say. A lot shyer, which is obviously an age thing as well and experience."* (CP3 P 6)

Half of the CP1 students said they believed that PBL students know more about CR, with 50% of that group guessing that although CR and the knowledge of

PBL students are probably more advanced, integrated students are not that far behind and the remaining students judged that there is no different at all. All of the CP3 students involved in this interview accepted that GEM students are a lot better at CR at the first clinical phase. The students supposed that GEM students have better CR skills but they are catching up with them very quickly. Many students deduced that GEM students have better CR because of the curriculum model. The UoN students concluded that they have done a lot of basic sciences, while GEM students have done a lot of clinical stuff. One student divulged that they would like to have PBL, expressing the view that most of the facts learned by students were only learned for the exams and would not apply in clinical cases. The students believed the better CR skills of the GEM students resulted form their confidence that came with their age. One student also mentioned the enthusiasms of GEM students. Many PBL students noticed a significant difference between the PBL students and integrated students in terms of reasoning, but indicated that PBL students have caught up. They visualised the PBL environment as a sort of ground for CR that put them quite far ahead of the integrated group.

- *"I think they're not massively ahead."* (CP1 9)
- *"I think comes together at pretty much a similar rate and maybe the GEMs have had a little bit more time to accumulate scientific knowledge, but I don't think there's a massive difference. No."* (CP1 10)
- *"They're used to not being spoon-fed and actually having to go and do it themselves whereas we've— learning what's in the lecture slides."* (CP1 8)
- *"I find it really helpful to have the solid systematic approach— they were already thinking in that direction, whereas we were still thinking in the*

opposite direction where if you told us, 'How does a heart attack present?' then we could tell you, 'Oh yes. Chest pain'— but if you said, 'You've got a patient with chest pain', we wouldn't necessarily have thought of a heart attack." (CP3 I 9)

- *"I've learnt all this biomedical science and stuff. I've not used any of it. I've learnt it's got me extra two points on my score— but you're never going to use that information. I've completely forgotten it. I forgot it five minutes after I left."* (CP3 I 2)
- *"It might just be a confidence thing and the fact that a lot of the GEM students are a lot older than the undergrads."* (CP3 I 10)
- *"There's not really a massive difference, and particularly now in fifth year – whereas maybe in CP1 it was much more pronounced."* (CP3 P 1)
- *"I think they learnt in the traditional way of lectures and workshops and things whereas we always had a clinical perspective – and how you're move forward as a doctor to deal with it, which helped us learn a lot of information very quickly."* (CP3 P 2)
- *"GEM (PBL) students are generally much more confident in saying their views, the UG (integrate) silence, I don't know whether that means they don't know or they just don't want to say."* (CP3 P 1)

Teacher's answers to the question "Have you noticed any difference in the CR from PBL students and integrated students?" are presented below. The three themes generated from this question are summarized in Table 4.6.

Table 4.6.
Themes for the Category of Differences in Learning (Teachers)

Themes
1. Many fellows revealed that PBL students show a bit more logical thoughts and step-wise reasoning and they might spot problems that the non-PBL students may not actually consider.
2. Four fellows expressed that there is no very noticeable difference in their clinical knowledge.
3. Three TFs believed that PBL trains the students in more critical reasoning way than the traditional methods.

The answers for this question are summarized as follows. Many fellows revealed that PBL students show more logical thoughts and step-wise reasoning and they might spot problems that the non-PBL students may not actually consider. Four fellows expressed that there was no very noticeable difference in their clinical knowledge. Two TFs stated that the Integrated students caught up and more at the same level at CP3. Three fellows declined to answer as he/she has not actually had exposure to a large number of GEM students to be able to make that comparison.

- *"Whether UGs (integrated) have learnt from GEMs (PBL), GEMs (PBL) have learnt from UGs (integrated), but they're much the same I think than they are at CP1."* (TF 5)

Three TFs believed that PBL trains the students in more critical reasoning way than the traditional methods. Two TFs made the declaration that it's hard to know how much of their CR is due to how they've been taught and how much is just due to their confidence and other variables. Three TFs mentioned that critical thinking is generated and in the own life and come with the experience. Two TFs claimed that it depends really on their background.

- *"In the traditional programmes— you've got a module— cell signalling, it's difficult to make decisions based purely on cell signalling."* (TF 8)

- *"They (PBL students) are more confident in general to express those opinions which perhaps the UG (integrated) are not- they may have a similar sort of level of understanding, but perhaps aren't willing to express it in that way."* (TF 5)
- *"Sometimes GEM (PBL) students have been physiotherapists or --- neuroscience or a nurse. ---So, they come with a lot of knowledge before they start the course. So, they're more accustomed to that process of CR."* (TF 3)

4.2.6. Opportunities for CR Learning

The answers of the students to the question "Are there any formal learning opportunities you have to develop your CR and what do you think about learning/teaching CR?" are presented below. The three themes generated from this question are summarized in Table 4.7.

Table 4.7.
Themes for the Category of Opportunities for CR Learning (Students)

Themes
1. Some participants said that CR is not taught, some students said that they have teaching on CR and some said CR teaching is additive process constantly although there is no formal teaching.
2. The students expressed barriers to learning CR include content factors, environmental factors, and teacher factors.
3. Some CP1 student think that CR is developed just naturally and could not be taught.

The answers for this question are summarized below.

a) Some participants said that CR is not taught, some students said that they have teaching on CR and some said CR teaching is additive process constantly although there is no formal teaching.

- *"As far as I know there's not been like a session on explaining what CR is or how to improve it for yourself."* (CP3 I 11)
- *"In fifth year, we've had CR sessions in emergency— So we have had targeted teaching on it."* (CP3 I 10)
- *"They do that (CR process) with a lot of teaching. So, it probably doesn't come labelled as CR"* (CP3 P 2)

b) The students expressed barriers to learning CR include content factors, environmental factors, and teacher factors.

- *"I think case-studies are really good actually— we had them earlier on— but they tend to be sort of in the wrong order and too soon— so people haven't really got a chance to try and learn the conditions before doing them."* (CP1 1)
- *"It's very difficult to sort of go through two years just learning in lectures to then three years to be like, 'Right. Remember all those things that you learnt and now apply them."* (CP1 I 6)
- *"The different locations that you're at, there is quite a difference in the style of teaching— some locations— had a lot of (radiology) teaching— but at other placements— I don't think they had— So there is a bit of discrepancy between the locations."* (CP3 I 11)
- *"Sometimes to have, 'This is a PE presents', and stuff like that because you do need to know it, but it cuts out that step of actually, 'How do you know it's a PE?', and it's quite nice having someone comes in with chest pain."* (CP3 I 4)
- *"Teaching is good for knowledge but not so good for CR."* (CP3 I 1)

- *"I got two resp clinics, a neuro, an endocrine, a gastro and a cardiac and that was it over the five weeks. So, it was like if you ended up with a— clinic but not variable people on the list, then you just didn't see them. And you got assigned to one ward. So, I was in endocrine. So, I only saw endocrine and general med patients. So, the only cardiac patients I saw would be in that one cardiac clinic. So, you don't get much exposure."* (CP3 I 2)
- *"The opportunities— been very good but I would like to have more. I know it's very difficult because the responsibilities of the multidisciplinary team. Resources are limited. So, we understand that sometimes that time can't be given.* (CP3 P 7)
- *"More exposure to our GP surgeries would be quite good because we only do— three or four days in total for the first year and second year— where you actually get a chance to see some CR."* (CP1 I 1)
- *"I think we do get to observe clinical practice but --- explanation given to us of what people are thinking as they go along--- because most people, when they've been in practice for a long time, --- becomes second nature and you don't actually think about why."* (CP3 P 4)

Some CP1 students concluded that CR is developed just naturally and could not be taught. CP1 students mentioned some challenges to learn CR such as early exposure before sound knowledge and within the first two years without emphasising CR and small opportunities to learn CR. CP3 students indicated a belief that CR is learned from experiential training and is not formally taught at UoN. They listed challenges for learning CR, including: environmental factors; the lack of emphasis on CR during the first two years; the variations in opportunities at different clinical

attachments; limited opportunities for learning CR; and full timetables. In the same group, some said they thought CR was a gradual process that could not be taught, while others believed it was important to teach. One student mentioned that they will only have to do actual CR once they begin their professional work. Three PBL students said that CR is taught but not labelled as CR. Reported barriers to teaching CR included the domain-specific knowledge required for teaching it, course structure, specific specialty attachments, and limited opportunities.

- *"It is almost not really touched on. --- Medical school don't really make it sound like it's important in your first and second years because it's so based on BMed Science, --- not really medicine."* (CP1 8)
- *"It's just almost like, 'Alright. Go away and learn the knowledge and then the rest of it will just fall into place', and in some respects I think that's true. There's very little teaching with CR."* (CP3 I 7)
- *"Actually, during the critical illness attachment, one of the teaching fellows here did a very, very interesting session on CR."* (CP3 I 3)
- *"Especially in the first year and second year. I feel like it's way too lecture-based just personally. I completely lost interest in some--- Just didn't seem very relevant --- now I've forgotten a lot of information --- if it had been more patient-based and --- making you think and work through it"* (CP3 I 5)
- *"It varies on placements. In CP1, I was in Derby so I had a lot of --- structured teaching with --- less ward time--- But then this placement --- they're trying to encourage CR --- I'm not sure if that's just because I'm at City Hospital --- or if it's because we're now in final year and they expect that from us.*" (CP3 I 1)

- *"I don't think it's something you can teach. It's natural. Like you can't sit down and give someone a lecture on CR."* (CP3 P 3)
- *"I would say that we had a lot of teaching actually on CR but it wasn't necessarily branded as CR teaching. So, it was sort of central to those different teaching aspects."* (CP3 P 1)
- *"CR's quite a tricky thing to teach. You can teach people what they need to know to make their judgements. So, you can teach us --- all the patient's history and --- all the investigations that are available for different things and --- all the pathology ---, but it's kind of up to you to piece the bits together from the different aspects to kind of do your CR. So, without sort of knowing the underlying basis of things, CR would be really difficult"* (CP3 P 3)

CP2 students had a range of specialties beyond general medicine and surgery. Facilitating CR skills was different from site to site. The difficulty the medical school had was in terms of providing that uniformity. Participants noted limited opportunities for practicing CR when patients are already worked out, also mentioning the lack of expertise and lack of seniors' time for facilitating the learning of CR.

- *"CP2's a difficult year because it's just bits and bobs and everything"* (CP3 P 6)
- *"There's quite a big gap between CP1 and CP3. ---but CR I think in psychiatry or in paediatrics can be a little bit different to the --- core medical and core surgical specialities. So, I --- feel a bit rusty at the start of CP3"* (CP 3 P 5)

- *"It's difficult with different sites for everyone to get a similar clinical exposure, but I think wherever you are, there are opportunities to gain good clinical experience and to improve your skills in CR"* (CP3 P 5)
- *"It's like learning backwards in the fact that you --- know that that person has this diagnosis, but how do you get to that diagnosis and it's just putting all the picture together. Because a lot of the teaching's around known pathologies in medical school --- and less so about actually, 'What is this?"* (CP3 P 6)

The teachers' views of teaching CR in UoN are presented below. Three themes were generated from this question and are summarized in Table 4.8.

Table 4.8.
Themes for the Category of Opportunities for CR Learning (Teachers)

Themes
1. More than half of the clinical teachers supposed that CR is not specifically taught at UoN.
2. Students still could learn by watching, by shadowing and by spending time on the wards and some clinical areas no matter where their attachment is.
3. The style of delivery which inhibits the development of CR like: Spoon-fed, parrot fashion learning, not trained to think and no time to reflect.

More than half of the clinical teachers supposed that CR was not specifically taught at UoN. One clinical teacher concluded that teaching in UG medical education is definitely improving. Factors affecting/ challenging the development of CR from TFs are briefly discussed in Chapter 4 as learning needs assessment for the faculty training. The learning environment presents many challenges. A few fellows said that the students still could learn by watching, by shadowing, and by spending time on the wards and in clinical areas regardless of where their specific attachments were. They also mentioned the style of delivery that inhibits the development of CR, including:

spoon-fed, parrot fashion learning, failure to train students to think, and not providing time to reflect.

- *"I don't think they get very much formal teaching on CR"* (TF 4)
- *"Now you've got people who've got dedicated time for teaching --- and generally will be doing some kind of teacher training. So ---, obviously teaching is going to improve."* (TF 5)
- *"It's one of the possible disadvantages of modulization, when each bit is seen as a stand-alone. Whereas CR is to do with integrating bits rather than taking them apart."* (TF 8)
- *"I'd say that the main one that the Clinical students at the moment have is their AMU (acute medical Unit) week where they have that time to see patients from when they are first admitted ---. I suspect when they're on wards and dealing with patients who have had the diagnosis and have treatment. They probably don't learn a lot there because the answer's already there."* (TF5)
- *"So, part of the students' curriculum, they have to attend clinics, they have to attend ward activities, and certainly all of that should include observing CR in action whether they overtly teach it or not."* (TF 9)
- *"The schedules are often too full so there is no enough time to go and do your self-directed things. I think it's tricky because there's an immense amount of knowledge to gather."* (TF 7)
- *"I think the shame is that perhaps a lot of what we see is you could learn in almost parrot-fashion sort of what's expected of you in terms of, 'I need to ask a certain number of questions and I need to cover certain areas, but*

I think that step further which turns you from student into a doctor is really gathering why --- do it and understanding purpose" (TF 6)

4.2.7. Process of Learning CR

Students answers to the question "How have you learnt CR?" are presented below. The five themes generated from this question are summarized in Table 4.9.

Table 4.9.
Themes for the Category of Process of Learning CR (Students)

Themes
1. In the pre-clinical years, many students from the Integrated curriculum did not feel there was much development of CR in preclinical years.
2. Some found it useful as a foundation for the first years of learning.
3. In the clinical years, students appreciated opportunities to learn CR.
4. In clinical years, six CP1 students believe they have not really learnt CR or had to put effort into learning CR in pre-clinical years
5. In pre-clinical years, PBL curriculum group strongly believed that they got exposure to CR fairly early on and it made them think about every situation from a clinical perspective.

In the pre-clinical years, many students from the integrated curriculum did not feel there was much development of CR in preclinical years. Some found it useful as a foundation for the first years of learning. Other sample responses are recorded below.

- *"I don't think there was much development in Year 1 and two."* (CP1 10)
- *"I found it really useful in terms of learning and figuring out --- how to think as a clinician because it's a different mind-set really from a student. It was good to get a good foundation during the first couple of years in GEM."* (CP3 P 2)
- *"I remember being in lectures. So, we'd have a whole module and then it would be an anatomy or physiology or whatever of that system, and then at the end there'd be two or three lectures that were clinical. So, they'd try to put in a scenario and then explain it using anatomy."* (CP3 I 1)

- *"We would have a weekly case (problem) and --- start by sort of brain-storming what could be the possible cause of whatever the presenting complaint was. So, I suppose that was the main component of our CR."* (CP3 P 1)
- *"Then obviously --- the SCR module --- further expanded"* (CP1 9)
- *"When we were doing anatomy, the exams for anatomy in both semesters included a unidirectional CR paper where we would be presented with a very basic case and you'd have to work your way through"* (CP3 I 9)
- *"In the end of the first year, they introduced exams around CR. So, they'll give a scenario of a little bit of information and then you have to say what questions you would ask, what investigations you would do, and what your differential diagnoses are. So, they start introducing it quite early. So that's useful because it's making people do examinations in that way and start thinking in that way rather than just regurgitating scientific knowledge"* (CP3 P 6)
- *"GEM (PBL) from day one we're sort of put in clinical situations and given actual patients and sent to real GP surgeries and things. So, from day one we're given that sort of environment to learn in."* (CP3 P 3)

In the clinical years, students appreciated opportunities to learn CR. A sample of responses is recorded below.

- *"If you don't have the knowledge, then you don't know what direction to aim in. You need Skills --- how to properly do the examinations and --- it works better if you have an understanding of what you're looking for as well."* (CP1 5)

- *"You can make lists of differential diagnoses for various symptoms that are quite common. So, shortness of breath! You can make a differential list and then come up with specific questions for that."* (CP3 I 10)
- *"Smaller groups. 'So, given this information, what do you think about this?', and then we'd talk it in the group in a safe environment."* (CP3 I 3)
- *"We had vignettes. So about five cases in a classroom where you're given the patient's obs, patient symptoms, and then you discuss the possible differentials as a small group, whereas actually having the lecture just on diseases, you have to go home and read it again, whereas being in charge of one particular scenario and being quizzed on it, I think that helps a lot."* (CP3 11)
- *"We've had workshops where we have six stations and we'll move around and --- practise our reasoning and --- have discussions with the healthcare professional that's running that station. I find that very, very helpful, because sometimes on the wards you might have an excellent patient with signs, but they may be preoccupied with other healthcare professionals and you don't want to get in the way because at the end of the day they need to be looked after. But if it's a run workshop with patients that have come in, that really helps because then you can just focus and then you don't have to wait on the ward for seven hours to listen a wheeze"* (CP3 P 7)
- *"We have these CR tests online --- those have been helpful in improving your knowledge but in terms of actively taking steps to improve my CR, apart from knowledge"* (CP3 I 11).

- *"We get bedside teaching. That's good to learn on the wards and ---, hands-on stuff, doing things. That's the best way I think to learn CR because then you can go back and read books---write up on it."* (CP1 2)
- *"I think being on the wards you learn it. So, I think we had foundations in GEM but it was only when I was properly exposed to the clinical environment that I realised how to implement it properly and what parts were useful and relevant. I think the investigation and the management is quite difficult to learn from a book because it varies so much between patient-to-patient. So, you have to have patient exposure before you can figure out what your plan is going to be from that point."* (CP3 P 2)
- *"The best thing for CR is around clinic work and ward rounds. So, you're observing other people doing their CR and actually, 'How did you get to that conclusion?' or, 'Why are you looking at those things?', and that starts putting the bits of information together that you can't get from a textbook."* (CP3 P 6)

In clinical years, six CP1 students believe they have not really learnt CR or had to put effort into learning CR in pre-clinical years. But case-based discussion in the small group and Scientific CR module definitely helped them developing this skill. They develop their CR in clinical years by putting together of everything. Three CP1 students said building knowledge is important. At least three students appreciated Simulation, one student thought workshops with real patients or actors are really enjoyable, one student added even case-based teachings purely with scenarios also has the value on developing CR and finally, eight students admitted that spending the time in the wards and seeing many patients allowed them to build their CR skills. While they are in the wards, they indicated a preference for having seniors watch them or

teach them. Students emphasised that they get more chance to apply their knowledge in acute-wards, since these patients have not worked out yet.

- *"I think it's a combination of everything --- the book knowledge --- be able to see a patient to link it all together. I always think --- this problem will present like this every time, but then you'll see a patient and it doesn't present like that. --- So, you need --- everything to really get a good idea of what's happening ---and improve your CR."* (CP1 5)
- *"Going around with the doctors on the wards and they tell you what they'd do next and then I've also done a bit of reading into it."* (CP1 7)
- *"The other students and doctors watching over us giving us advice. I like that because you learn as you're going along and then you can sit back and reflect on what you've done."* (CP1 2)

In pre-clinical years, three CP3 students recalled that they did not learnt CR in the first couples of years, but said they appreciated online formative tests and lectures on applied anatomy or physiology. In clinical years, CP3 students mentioned improving knowledge, symptom-based teaching and mind maps, case-based teaching /PBL, simulations, and workshops. Seven CP3 students favourably mentioned CR tests. Seven CP3 students said going to the wards and talking to the patients can help develop CR skills, providing hands-on experience with feedback in place of passive observing and teaching. They emphasised acute wards, MAU, ED, and GP as the best places for developing reasoning. Six CP3 students reported learning CR by observing how doctors did it.

- *"Teach you algorithmic type ways are quite helpful because that is CR. It --- can help you to point yourself in the direction. It's like chest pain. You can literally like an algorithm saying, 'Does it radiate to the back? It is*

likely to be a dissecting aneurysm. It --- changed my way of thinking---you link it all together to make this big spider diagram or drop-down list in your head" (CP3 I 6)

- *"The simulations have accelerated it so much. It's such a big period of learning because I knew about DKA before ---. It's literally nothing new but to see it in front of you and think about the factors, it's accelerated it.* (CP3 I 6)
- *"It puts you in the situation of the doctor. 'So, what are you going to do for this patient?' ---' Rather than being told, --- you put yourself in the doctor's shoes in that case. It forces you to think. I think it helps you remember as well. "*(CP3 11)
- *"I quite like ED anyway because there was a lot of opportunity to see snapshots of people. GP obviously --- the volume of patients you can see in a short space of time. If you're on a gastro ward here, you'd probably exhaust your list of patients quite quickly."* (CP3 7)

In pre-clinical years, the PBL curriculum group strongly believed that they got exposure to CR fairly early on, helping them to think about every situation from a clinical perspective. They also had formal CR teaching as well. In PBL curricula, they always use case-based teaching. CR online tests also allowed them to build their skills in CR, as did early clinical exposure and interactions with real patients. In clinical years, the students learned their CR through symptom-based discussions, case-based teaching or presentations, patient workshops, patient -based discussions, hands-on experience, observations of clinicians, and seeing the patients on the ward. Some students added that they have developed their reasoning by attending cased based

presentations and teaching rather than physically seeing the patients. Such forums gave students opportunities to go through cases in a simulated way in lectures.

- "It was in *GEM that really introduced the idea of CR, evidence-based medicine"* (CP3 P 6)

The sample of teachers was asked the same question. The two themes generated from this question are summarized in Table 4.10.

Table 4.10.
Themes for the Category of Process of Learning CR (Teachers)

Themes
1. Most fellows incorporated CR by case-based interventions such as case-based discussions, using real patients, pictures, role-play and simulated patients and debriefing.
2. Their journey of learning CR as in expert performance, deliberate practice, and experiential learning.

Three teachers explained that their journey of learning CR came through expert performance, deliberate practice, and experiential learning. One teacher recalled developing CR by seeing many patients on the wards and CBD.

- *"Based on your experiences in the past, you obviously modify each of your future managements based on what went well or didn't go well in previous encounters with that particular condition. Then I think the more you do that, the more experienced you get"* (TF 3)

The clinical teachers also mentioned a list of educational interventions, with 89% of fellows reporting the incorporation of CR through case-based interventions such as case-based discussions, the use of real patients, pictures, role-play, patient simulations, and debriefing. They also thought building a solid base of medical knowledge was a key element for developing CR. Three teachers alleged that their teaching was more focused on "why" rather than "what" to explore their reasoning

process rather than just outcomes**.** One fellow reported making sure students saw as many cases as possible. The more cases the students can see, the better opportunities they have for developing their CR. Finally, one fellow reported deliberately designing the scenarios and discusses dual process theory, cognitive forcing strategies, and de-biasing strategies.

- *"When there's a patient in front of the student, that you can then say, 'And what will you do next?' and then you can explore some of that CR, explore why that might be a good decision and what the reasoning behind that is, why that might not be such a good decision.* (TF 4)
- *"Even something as simple as taking your blood pressure, you can teach it by itself ---, student can learn exactly what to do, but how you make sense of it, and --- 'What does this mean?' ---. Look at the slightly bigger picture."*(TF 8)
- *"If I have UGs on the ward, then I try and show them a spectrum --- avoid, just seeing all pneumonia cases because then they feel like everyone who's breathless in hospital during winter --- pneumonia. You have to think, 'could this be a GI problem? Could this be a cardiology problem?' So, it's using that to just make it clear that it doesn't always fit with one diagnosis."* (TF 7)
- *"I think role-modelling is a strong aspect."* (TF 4)
- *"I teach them to understand hypothetic deductive model, remind pattern recognition is dangerous at this stage and ask them to go step by step approach and force them to change reasoning. I tell the group about possible biases for diagnosis"* (TF 2)

4.2.8. Curricular Improvements

Student answers to the question "How could we emphasise CR more?" are presented below. Responses addressed the ways students would like the teachers to deliver CR, showing similarities to previous discussion regarding the learning opportunities that helped them to develop CR. The three themes generated from this question are summarized in Table 4.11.

Table 4.11.
Themes for the Thematic Category Curricular Improvements (Students)

Themes
1. The CP1 students mention many styles of delivery of the course that could facilitate their CR development in both preclinical years and clinical years.
2. In pre-clinical years, seven students would like to put more emphasis on CR from an earlier stage. In clinical years, the students are asking for more symptoms-based teaching, formative online tests, simulations, case-based teaching and chances to work on the acute wards.
3. PBL curriculum group did not say anything more to change the way the school taught in their pre-clinical years apart from few lectures on CR

The CP1 students mentioned styles of material delivery that could facilitate their CR development in both preclinical years and clinical years. In pre-clinical years, even in the theory teaching, CR could be incorporated better by introducing CR in lectures, by emphasizing applied basic sciences, by providing case-based interventions such as online tests, by employing problem or case-based sessions, through simulation, and by providing early clinical exposure. In clinical years, different forms of case-based interventions are believed to improve their CR development from symptom-based teaching, simulation to actively hands on practicing with real patients.

- *"Telling you that explicitly like, 'This (CR) is a thing that you need to learn how to do'. --- mentioning it earlier makes you more aware of it."* (CP1 3)

- *"Just doing like case-based scenarios because the first two-and-a-half years it's very theory-heavy. It doesn't feel like it's clinically related. So just relating the content back to how it would be used in practice ---"* (CP1 3)
- *"I think what I quite like to do is just learn what the differential diagnoses are of the symptoms and then so if I go through all of them --- think what to exclude which is what I'm doing a bit more --- each week to sort of learn a bit more from that."* (CP1 1)
- *"I would say more simulations---. you don't forget about it as easily as you do just reading,"* (CP1 6)
- *"Go find a few cases. We'll all do some history-taking, some examinations, and then we'll come back and discuss the cases (with seniors) as well. I just feel like that's the best way to do it. ---I could do that myself but --- but with a consultant, you know exactly that what you're talking about is right and he'll teach you all the important things as well."* (CP1 8)

CP3 students in the integrated curriculum expressed opinions similar to those expressed by the CP1 group. In pre-clinical years, seven students said they would appreciate more emphasis on CR from an earlier stage. In clinical years, students asked for more symptom-based teaching, formative online tests, simulations, case-based teaching, and chances to work on the acute wards.

- *"I don't think it was --- actively addressed --- this is why you're asking these, --- it was sort of left to me to --- discover for myself."* (CP3 I 3)
- *"I think if they're phasing out the B. Med Sci, to introduce a far more clinical approach early on with --- a focus on pathology rather than molecular structure --- to allow more time for CR."* (CP3 I 9)

- *"Obviously helping us develop algorithms for --- many common symptoms.*
- *"We're taught to look at the conditions and find out the symptoms. We should be looking at the symptoms and what are the causes because realistically nobody's going to come in and say like, 'I've got an aortic aneurism'. They --- say, 'I've got abdominal pain'"* (CP3 I 6)
- *"In lectures as well, having cases --- is really helpful. --- if you're not given all the information at once, forced to think, 'What's going on with this case?', and then afterwards they add in the examination findings and then the investigation findings and it's a practical way to practise CR even though it's in a lecture setting."* (CP3 I10)
- *"We need more simulation days. --- In an ideal universe you'd have a day like this in every attachment that focused on scenarios within that attachment and that would prepare us really well"* (CP3 I 9)
- *"If I was an F1 and I --- would probably tell them, --- 'if you put yourself in my shoes and --- what is the information that I need to assess this patient?','* (CP3 I 11)
- *"I do think you need to spend lots of time on the wards because you need to be good, confident with the practical aspects, and how a ward runs, but you get the CR from going to SAU and MAU and ED, because you don't know what's wrong with them. If you find them on cardiology --- I expect to hear a murmur."* (CP3 I 7)

The PBL curriculum group did not say recommend any changes to the way the school taught during their pre-clinical years, apart from noting the few lectures on CR that were provided. In clinical years, however, they expressed a desire to have CR be taught explicitly, to have formal flow charts for different presentations, and to include

small-group, ward-based teaching with discussion. One student added that getting feedback is really important to develop CR and expressed a wish for video recording and feedback.

- "*Why we don't use video feedback because – you – can start to see things, all those cues, and see what everybody else sees when they see you. 'So why are you doing this and what are you doing here?'"* (CP3 P 6).

The same question was asked for the sample of teachers. Teachers' perspectives on how to emphasise CR more in the curriculum are presented below. Two themes were generated from this question and are summarized in Table 4.12.

Table 4.12.
Themes for the Category of Curricular Improvements (Teachers)

Themes
1. Role modelling
2. Should be taught in central teaching and emphasized throughout the educational continuum

Two TFs said that CR should be taught in central teaching and emphasized throughout the educational continuum. They believed that step would yield more opportunities for simulation and debrief, for hands-on experiences in the wards, for opportunities to see many patients, and for chances to follow the journeys of patients. Four TFs mentioned role modelling.

- *"It should be a theme that runs through the course rather than try and pin down their decision-making. I think within each bit of the course, it needs to be flagged and --- part of philosophy rather than, 'Let's do this so we can tick a box'. It should be an integral part of what we do"* (TF 8)

- *"The simulation work --- because again that's --- a specific patient with specific issues where again you can have an opportunity to debrief afterwards."* (TF 4)
- *"Again, the idea is to force a commitment from your students. So, creating --- an atmosphere --- where they can venture their thoughts and their diagnosis and try and push it into a diagnosis. Getting that CR process to --- put it into gear and start it happening."* (TF 6)
- *"It's clearly an on-going process, --- developing the instant scripts. Seeing lots and lots of cases and lots of patients take a lot of time and there is no sort of short-cut or substitute for experience."* (TF 6)
- *"I don't know to what extent the students follow a patient journey. --- Obviously a lot of our on the ward teaching is just brief exposure to patients --- regularly being with a team might help to build that in.* (TF 9)
- *"I think the students pick up critical thinking or they emulate it if they like a consultant, the way he approaches the patient and the problem-solving."* (TF 1)
- *"I think there is a role clearly for teaching CR, and by selecting cases that on face-value --- it's a spot diagnosis, but then on delving further, it turns out to be a different diagnosis. --- It's important to include that variety in case studies --- that you have to dig a bit deeper. You have to explore certain cues in the history and you have to be aware when something doesn't a particular pattern and not force a clinical presentation into the diagnosis you've got in your head. ---, try and explore what else could be going so just ask that question. So, a mixture of teaching them but actually*

them doing the job and reflecting on the mistakes that they've made and any misses that they've had (TF 7).

- *"One-minute preceptor ---where you don't need --- take a long time but you can force a bit of engagement and try and get an answer or get a commitment out of the learner "*(TF 6)
- *"Watching the consultant take twenty histories in a row is pretty useless, because they skip all --- CR steps because they can and they don't vocalise it. So, we don't learn from it. Whereas maybe there needs to be more formal teaching"* (TF 3)
- *"I guess diagnosis is a large part of what most doctors do. So, it seems to make sense to teach it in a slightly more formal explicit way."* (TF 7)

4.2.9. Assessment of CR

The answers of the students to the question "Do you think that CR is assessed in knowledge papers?" are presented below. The two themes generated from this question are summarized in Table 4.13.

Table 4.13.
Themes for the Category of Assessment of CR (Students)

Themes
1. Some participants did not think CR is assessed
2. Some supposed there were some questions that assessed CR across all the clinical years.

Some participants said they did not think CR was assessed, while others supposed there were some questions that assessed CR across all the clinical years. The PBL group had separate CR papers in Year 1 and Year 2, while participants from the integrated group offered only one comment that CR was not assessed in the preclinical years. CR was not tested in Year 1 and Year 2 papers, but PBL students

had formal CR exams. There were two opposite views expressed regarding assessment of CR during the clinical years.

- *"So as part of GEM course, we had CR exams---. So that was a very obvious test."* (CP3 P 1)
- *"No. I don't think they really are assessing our CR. They're more assessing knowledge."* (CP1 I 2)
- *"Yeah they assess because I was asking you to interpret things and say, 'What's mostly likely from these results?'"* (CP1 I 3)
- *"I am in finals but I don't think I've ever been assessed on my CR up until then"* (CP3 I 7).
- *"I think they are assessed --- in CP2."* (CP3 I 3)
- *"No. Not really. I don't know actually. Probably not as much as I think we probably should"* (CP3 G 2)
- *"I think it is actually--- Certainly more and more! --- Now I feel my exam is going to be very heavily focused on that and that's the main thing to focus on this year"* (CP3 I 3)

The answers of the students to the question "Do you think CR is assessed in objective structured clinical examinations (OSCE)s?" are presented below. CP1 has OSLER/OSCE in their assessment, whereas CP3 students have 2 sets of OSCEs (OSCE1 and OSCE2). CR was not highlighted in Year 1 and Year 2 OSCE. For the CP1 objective structure long examination record (OSLER), CP1 students thought that CR was assessed, but CP3 students disagreed. All CP 1 students thought that every step, from taking history to managing in OSLER, was CR. But CP3 students did not think that CR was measured in CP1. One student clearly mentioned that he/she had not ever been assessed on CR up until CP3, while another student said that some

elements of CR were tested. One student said that there was not much emphasis on CR even in CP3, while others added that CR was tested at basic levels. Some said that there was more CR in the exams.

- *"The first and the second year OSCEs were just like these six station-based things and as soon as you'd done that one, you were done with it."* (CP1 I 2)
- *"From my understanding, taking a history, that's CR in itself. Then trying to choose your questions to fit into what you think is going to be a differential diagnosis. Then picking what examination you're going to do, so --- it is assessed."* (CP1 I 8)
- *"Actual diagnosis might not count. So, it's being able to perform the skills, ---, pick up all the signs, but without that CR"* (CP3 I 8)
- *"Because that was a forty-five-minute history and then you presented it and --- few different things that it might be (to the patient). It wouldn't even have to be right. That wasn't part of the mark, because as long as you've said it in an empathetic tone, you still pass the station. So actually, you're not testing CR at all"* (CP3 I 7)
- *"In the CP2 OSCEs where we're presented with a short case and asked to think about CR and how we'd manage a patient."* (CP3 P 5)
- *"No because the OSCEs, you can just do the motions, not a clue what you're talking about but you've ticked the boxes. "*(CP3 I 4)
- *"I think probably to a certain extent it is because if you're given a case in the exam and you're asked to make clinical judgements, --- then you're reasoning with the information that you've been given."* (CP3 I 11)

- *"More CR because you get given a patient. You take a history. Do a focused examination and then, 'Tell me what your differentials are?' That feels a lot more CR."* (CP 3 P 2)

These interviews were carried out for CP1 students and they had not sat this OSLER yet so they didn't know about their OSLER in details. All of them, however, said they believed CR had been assessed**.** They reported having to take history, give some differential diagnoses, and present it back in order to demonstrate that they were thinking more clinically and logically to get the answer. Interviews were carried out for current CP3 students who had not sat OSCE 2 yet and therefore didn't know about that in detail. Few students thought that CR was not tested even in the OSCEs and OSLERS. More than half of the CP3 PBL students stated that CR was tested in OSCE, especially in OSCE 2, but was tested only up to the basic level.

- *"A lot is all about your history-taking skill and how you use your CR to sort of focus in on the things you need to focus, otherwise you will run out of time. So yes. I would say the OSLER is mostly CR."* (CP1 I 10)
- "*There's no CR there whatsoever. Anyone could have passed that as long as you followed the correct steps and you could have trained a geography student to pass that exam" (CP3 I 7)*
- *"Not a lot. As long as you know the basics! Obviously as F1s, we're under supervision, we need our basic CR to basic management, and I think that's tested in the OSCEs."* (CP3 P 7)

Teachers' perspectives on whether CR is assessed in the knowledge papers are presented below. Two themes were generated from this question and are summarized in Table 4.14.

Table 4.14.
Themes for the Category of Assessment of CR (Teachers)

Themes
1. They have not seen the knowledge papers yet.
2. Some fellows are not sure whether CR can be assessed or not at UG levels in the exam settings

Thirty-three percent of clinical teachers who were involved in this interview admitted that they have not seen the knowledge papers yet. Some fellows are not sure whether CR can be assessed or not at UG levels in the exam settings.

- *"I don't have a great deal of experience of what exactly is in the knowledge paper. I haven't been writing any questions. I haven't seen the questions."* (TF 4)
- *"Can you assess CR? I mean I'm sure you can assess CR in clinical practice by looking at specific situations and incidents and events and people and families, to look at how the student makes their decision. I mean you could assess on a paper exercise by having lots of bits of information and ask the students to pull them together and make sense of them?"* (TF 8)
- *"It is very difficult to separate CR from academic knowledge so I am not sure it is evidence to say we assessed"* (TF 2).
- *"I am aware of particular type of questions that are better to assess. It does play a part in some of the questions."* (TF 2).

Teachers' views on whether CR is assessed through OSCE are presented below. One fellow said that he/she could not answer directly. Participants emphasized CR assessment further down the medical school.

- *"I know OSCE 2 and OSCE 1, students have to reason under such pressure, based on clinical knowledge. I think somehow represented in the performance. I could not answer."* (T 2)
- *"I think even OSCE 1 I've seen CR used. I was part of a station last year for OSCE 1, ---They had to take a history and then do a urine dip-stick and then explain to the patient what the test showed and what would happen now. So that's a fair amount of CR."* (T 5)
- *"In OSCE 2 there's got to be CR because they get a patient and they have to investigate it and find out lots of bits of information and try and make sense of it."* (T 8)

4.3. QUANTITATIVE RESULTS

This section outlines the results of the data analysis for each of the quantitative research questions.

- This new curriculum is effective in developing CR skills for students and also in developing the teaching of CR skills for the teachers.
- Participants in clinical case scenarios have significantly greater CR scores in the summative written exam in CP3 data sets.
- The students with full CR teaching showed a positive effect on their CR score. CR scores of students were highest at the period of full CR teaching implementation.
- The curricular phase and the exposure to clinical practices have an impact on the development of CR.
- All problem-based learning (PBL) students scored better than integrated students on the CR component of the summative exam in the CP1 dataset in the three periods. However, there was no significant difference in the

CR scores between the PBL students and integrated students in the CP3 dataset.

- There was no association between students' genders and their performance in CR.

4.3.1. Normality

Normality test of the data of the different dependent variables should be conducted to ensure that the data meets normality. This study involved the use of parametric statistical tests of ANOVA and independent sample t-test to address the research objectives of the study. The parametric test requires the data of the dependent variable to be normally distributed. The dependent variables included the CR scores, NCR scores, and total scores of summative written exams for each of the dataset of CP1 and CP3 datasets. Normality testing was conducted by investigation of the skewness and kurtosis statistics and histogram to check the distribution of data of the different dependent variable.

To determine whether the data follows normal distribution, skewness statistics greater than three indicate strong non-normality and kurtosis statistics between 10 and 20 indicated non-normality (Kline, 2005). As can be seen in Table 4.15, the range of values were in the acceptable range for: skewness (-0.35 to 0.63) and kurtosis statistic (-0.79 to -0.13) for the dependent variables of CR scores, NCR scores, and total scores of summative written exam for the CP1 dataset; and skewness (-0.30 to 0.26) and kurtosis (-1.02 to 0.49) statistic for the dependent variables of CR scores, NCR scores, and total scores of summative written exam for papers 1 and 2 for the CP3 dataset. Those values indicated that all the data of these dependent variables exhibited normal distribution. Upon checking the histograms in Figures 4.2 and 4.2, the researcher concluded that bell-shaped curves representing a normal distribution were

exhibited in the different plots in both the CP1 and CP3 datasets for the dependent variables of CR scores, NCR scores, and total scores of summative written exam. Although the bell-shaped curves represented were not perfect, they were represented in each of the graphs. With these results, the data of all dependent variables in both the CP1 and CP3 datasets exhibited normality. Thus, the parametric statistical analyses could be conducted.

Table 4.15.
Skewness and Kurtosis Statistics of CR Scores, NCR Scores, and Total Scores of Summative Written Exam for CP1 Dataset

		Skewness		Kurtosis	
	N statistic	Statistic	Std. error	Statistic	Std. error
CR	1022	0.63	0.08	-0.15	0.15
NCR	1020	0.04	0.08	-0.79	0.15
Summative written exams	1021	-0.35	0.08	-0.13	0.15

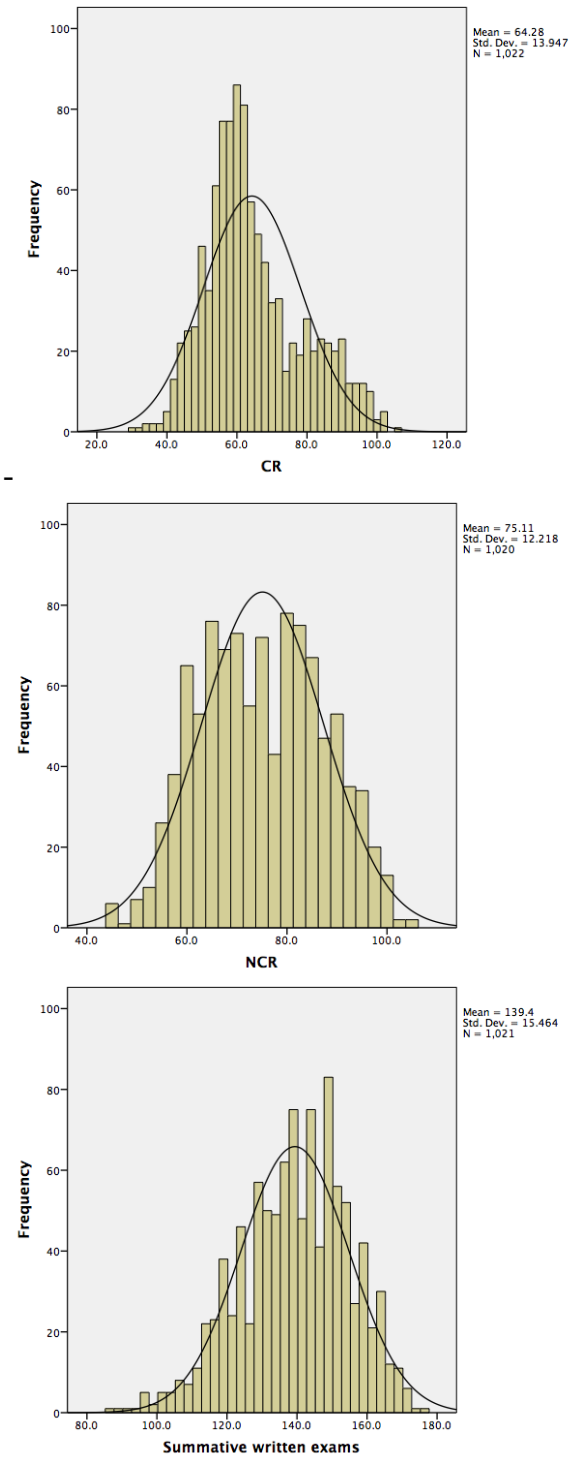
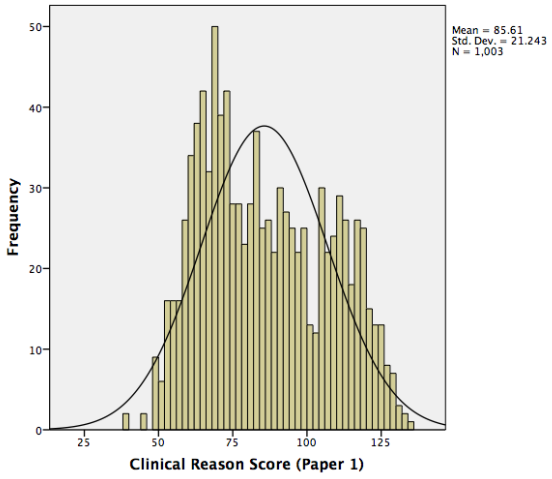
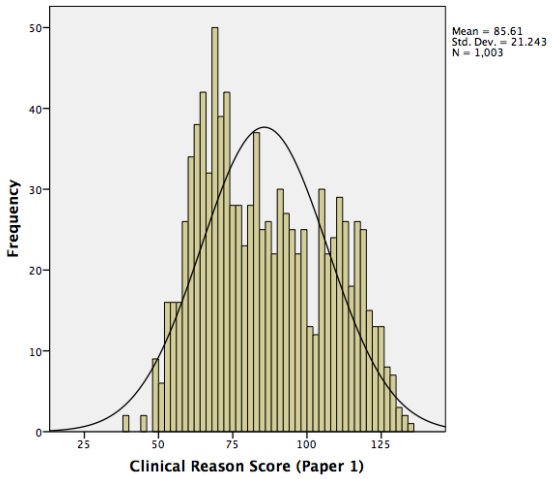


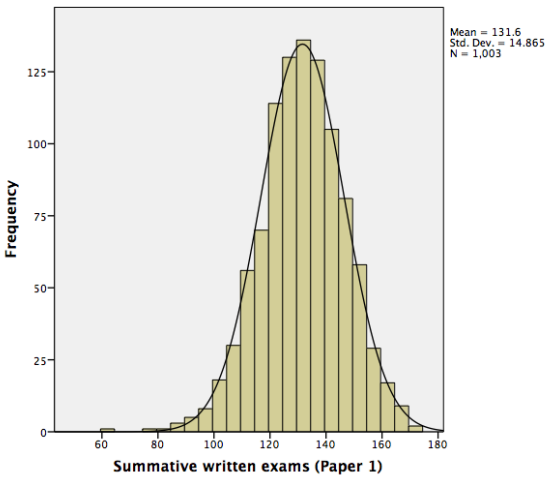
Figure 4.1. Histogram of Data of SR Scores, NCR Scores, and Total Scores of Summative Written Exam for CP1 Dataset

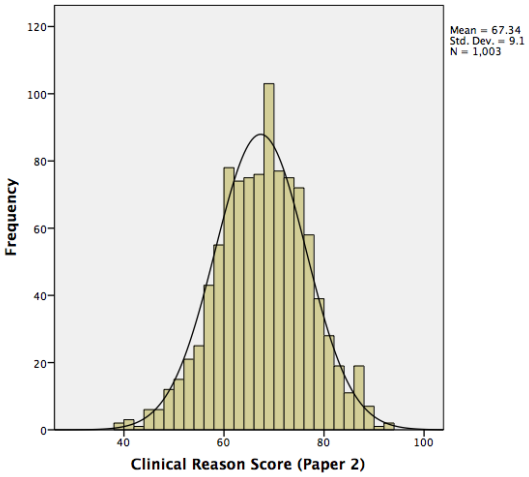
Table 4.16.
Skewness and Kurtosis Statistics of Scores of CR Scores, NCR Scores, and Total Scores of Summative Written Exam for CP3 Dataset

		Skewness		Kurtosis	
	N statistic	Statistic	Std. error	Statistic	Std. error
CR Score (Paper 1)	1003	0.26	0.08	-1.02	0.15
NCR Paper 1, 41/192	1003	0.10	0.08	-1.02	0.15
Summative written exams (Paper 1)	1003	-0.28	0.08	0.49	0.15
CR (Paper 2)	1003	-0.11	0.08	-0.01	0.15
NCR paper 2, 98/185	1003	0.23	0.08	-0.35	0.15
Summative written exams (Paper 2)	1003	-0.30	0.08	0.01	0.15






Mean = 131.6
Std. Dev. = 14.865
N = 1,003
Frequency
Summative written exams (Paper 1)


Mean = 67.34
Std. Dev. = 9.1
N = 1,003
Frequency
Clinical Reason Score (Paper 2)

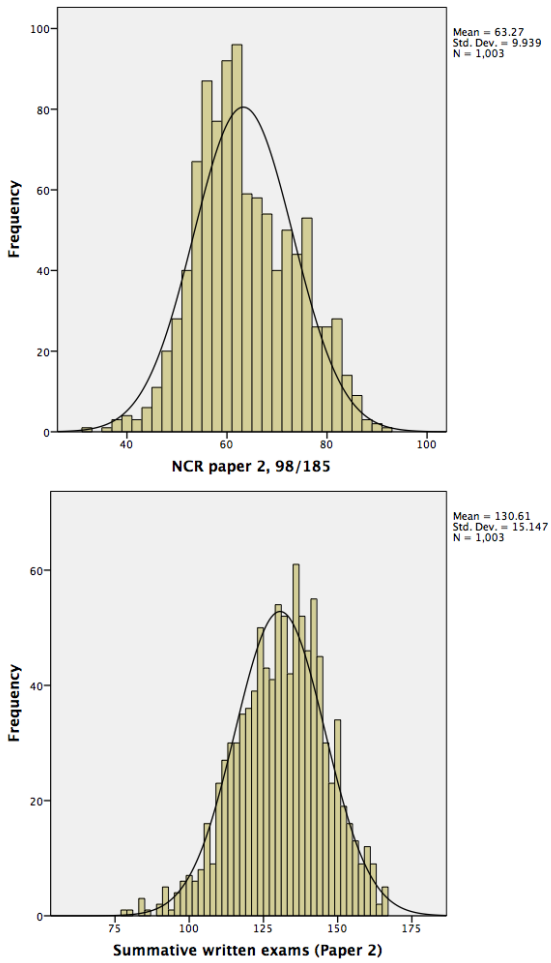


Figure 4.2. Histogram of Data of CR Scores, NCR Scores, and Total Scores of Summative Written Exam for CP3 Dataset.

4.3.2. Impact of CCS CR Teaching Participation on CR

The first quantitative research question asked: "Does the participation in CCS CR teaching curriculum model influence outcomes as measured by summative written exams?"

$H0_1$: There is no significant effect from the participation in CCS CR teaching.

Ha_1: There is a significant effect from the participation in CCS CR teaching.

ANOVA analysis was conducted to determine the effect of CCS CR teaching participation. A level of significance of 0.05 was used in the ANOVA. Different analyses were conducted on the dataset of CP1 and CP3. Results showed a significant

difference in scores when the *p*-value was less than or equal to the level of significance value.

Table 4.17 summarizes the ANOVA results for the CP1 dataset. The results of the ANOVA showed that outcomes as measured by the CR scores in the summative written exam (F (4, 666) = 41.46, $p < 0.001$) were significantly different among differences of frequencies of participation in CCS CR teaching curriculum model. This was because the p-value was less than the level of significance value of 0.05.

Table 4.17. *ANOVA Results of Difference of CR Scored by Frequencies of Participation in Clinical Case Scenarios for CP1 Dataset*

	Sum of squares	df	Mean square	F	Sig.
Between groups	29799.40	4	7449.85	41.46	0.00*
Within groups	119682.91	666	179.70		
Total	149482.31	670			

* Significant difference at the 0.05 level of significance

Post-hoc test results in Table 4.18 using Tukey's test showed that those who did not participate in CCS (M = 75.93; SD = 15.05) had significantly greater CR scores in the summative written exam than those who participated in CCS for frequencies of two times (M = 66.50; SD = 14.69), three times (M = 62.42; SD = 13.77), and four times (M = 60.39; SD = 10.51) by mean differences of 9.44, 13.52, and 15.55, respectively. Those who participated in clinical case scenarios for a frequency of one time (M = 76.35; SD = 13.68) had significantly greater CR scores in the summative written exam than those who participated in CCS for frequencies of two times (M = 66.50; SD = 14.69), three times (M = 62.42; SD = 13.77) and four times (M = 60.39; SD = 10.51) by mean differences of 9.86, 13.94, and 15.97, respectively. Those who participated in CCS for a frequency of two times (M = 66.50;

SD = 14.69) had significantly greater CR scores in the summative written exam than those who participated in clinical case scenarios for frequencies of four times (*M* = 60.39; SD = 10.51) by a mean difference of 6.11

Table 4.18.

Post-hoc Test Results of Differences of CR Scores by Frequencies of Participation in Clinical Case Scenarios for CP1 Dataset

(I) Frequency of participation in clinical case scenarios	(J) Frequency of participation in clinical case scenarios	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
0	1	-0.42	1.86	1.00	-5.51	4.67
	2	9.44*	1.90	0.00	4.23	14.64
	3	13.52*	1.94	0.00	8.20	18.84
	4	15.55*	1.87	0.00	10.45	20.65
1	2	9.86*	1.53	0.00	5.66	14.05
	3	13.94*	1.58	0.00	9.60	18.27
	4	15.97*	1.49	0.00	11.90	20.04
2	3	4.08	1.63	0.09	-0.39	8.55
	4	6.11*	1.54	0.00	1.90	10.33
3	4	2.03	1.59	0.71	-2.32	6.38

*. The mean difference is significant at the 0.05 level of significance.

Table 4.19 summarizes the ANOVA results for the CP3 dataset. The results of the ANOVA showed that outcomes as measured by the CR score in the summative written exam Paper 1 (F (4, 663) = 2.60, p = 0.04) and Paper 2 (F (4, 663) = 3.00, p = 0.02) were both significantly different among differences of frequencies of participation in CCS CR teaching curriculum model. This was because the p-values were less than the level of significance value of 0.05.

Table 4.19.
ANOVA Results of Difference of CR Scores by Frequencies of Participation in Clinical Case Scenarios for CP3 Dataset

		Sum of squares	df	Mean square	F	Sig.
CR Score (Paper 1)	Between groups	1696.40	4	424.10	2.60	0.04*
	Within groups	108170.50	663	163.15		
	Total	109866.90	667			
CR Score (Paper 2)	Between groups	1195.59	4	298.90	3.00	0.02*
	Within groups	66085.20	663	99.68		
	Total	67280.80	667			

*. Significant difference at the 0.05 level of significance

Post-hoc test results in Table 4.20 using Tukey's test showed that those who participated in CCS for a frequency of four times (M = 75.36; SD = 11.88) had significantly higher CR scores in the summative written exam Paper 1 than those who did not participated in CCS (M = 70.22; SD = 13.22) by a mean difference of 5.14. Those who participated in CCS for a frequency of one time (M = 69; SD = 9.81) had significantly higher CR scores on the summative written exam Paper 2 than those who did not participated in CCS (M = 66.29; SD = 9.90), by a mean difference of 3.53.

Table 4.20.
Post-hoc Test Results of Difference of CR Scores by Frequencies of Participation in Clinical Case Scenarios for CP3 Dataset

Dependent variable	(I) Frequency of participation in clinical case scenarios	(J) Frequency of participation in clinical case scenarios	Mean difference (I-J)	Std. error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
CR Score (Paper 1)	0	1	-4.14	1.66	0.09	-8.67	0.40
		2	-2.43	1.60	0.55	-6.79	1.93
		3	-3.38	1.67	0.26	-7.94	1.19
		4	-5.14*	1.74	0.03	-9.91	-0.38
	1	2	1.71	1.45	0.76	-2.25	5.66
		3	0.76	1.53	0.99	-3.42	4.94
		4	-1.01	1.61	0.97	-5.40	3.39
	2	3	-0.94	1.46	0.97	-4.94	3.05
		4	-2.71	1.54	0.40	-6.93	1.50
	3	4	-1.77	1.62	0.81	-6.20	2.66
CR Score (Paper 2)	0	1	-3.53*	1.30	0.05	-7.07	0.02
		2	-0.69	1.25	0.98	-4.10	2.72
		3	-2.63	1.31	0.26	-6.20	0.95
		4	-2.96	1.36	0.19	-6.68	0.76
	1	2	2.84	1.13	0.09	-0.25	5.93
		3	0.90	1.20	0.94	-2.37	4.17
		4	0.56	1.26	0.99	-2.87	4.00
	2	3	-1.94	1.14	0.44	-5.06	1.18
		4	-2.28	1.20	0.32	-5.57	1.02
	3	4	-0.34	1.27	1.00	-3.80	3.13

*. The mean difference is significant at the 0.05 level of significance

With these results for both the dataset of CP1 and CP3, the null hypothesis for RQ1 (that there would not be a significant effect from the participation in CCS CR teaching curriculum model on outcomes as measured by CR scores in the summative written exams) was rejected. The result of the ANOVA showed that there was a significant effect from the participation in CCS CR teaching. Although there was some significant effect from the participation in CCS CR teaching curriculum model on outcomes, it did not necessarily mean that the students who participated in CCS CR teaching curriculum model achieved higher scores than who did not participate. In CP1, the students who participated only one time got the highest scores, meaning that they scored higher than those who participated in zero cases, two cases, three cases, or four cases. However, on CP3 Paper 1, the students who did all four CCS CRs scored higher CR marks than other groups as exhibited in the test of difference results in the CP3 dataset. On CP3 Paper 2, the students who did clinical cases four times scored higher than other groups apart from the group of students who did only one case.

4.3.3. Impact of Course Redesign on CR

Quantitative RQ3 asked: "Does the redesign of the course each year improve the performance of CR curriculum?"

$H0_3$: There is no significant effect on the CR teaching/implementation process.

Ha_3: There is a significant effect on the CR teaching/implementation process.

This was a vertical study in which the researcher followed changes to the CR course each year concerning its implementation and the effect on summative assessment. ANOVA was conducted to determine whether the CR teaching process had significant impact on course elevations as measured by the CR scores. Total

scores in the summative written exams were significantly different between the three school years, which had differences in implementation in CR teaching. Different analyses were conducted on the datasets of CP1 and CP3. A level of significance of 0.05 was used in the ANOVA.

Table 4.21 summarizes the ANOVA results for the CP1 dataset. For the CP1 dataset, there was no CR teaching in the year 2012, partial CR teaching in the year 2013, and full CR teaching in the year 2014. The results of the ANOVA showed that the CR scores (F (2, 1019) = 698.85, $p < 0.001$) and total score in the summative written exam (F (2, 1018) = 38.62, $p < 0.001$) were significantly different during the three school years of differences in implementation in CR teaching for the CP1 dataset. This was because the p-values were less than the level of significance value of 0.05.

Table 4.21.
ANOVA Results of Difference of CR Scores and Total Scores of Summative Written Exams in Different Period of CR Teaching Implementation Status for CP1 Dataset

		Sum of squares	df	Mean square	F	Sig.
CR	Between groups	114866.89	2	57433.44	698.85	0.00*
	Within groups	83743.75	1019	82.18		
	Total	198610.64	1021			
Summative written exams	Between groups	17200.07	2	8600.04	38.62	0.00*
	Within groups	226723.48	1018	222.72		
	Total	243923.55	1020			

* Significant difference at the 0.05 level of significance.

Post-hoc test results in Table 4.22 using Tukey's test showed that the CR scores were significantly higher in the period of full CR teaching (M = 79.71; SD = 11.41) than in the period of no CR teaching (M = 57.66; SD = 8.58) by a mean difference of 22.05. Also, CR scores were significantly higher in the period of full CR teaching (M = 79.71; SD = 11.41) than in the period of partial CR teaching (M = 56.35; SD = 6.73) by a mean difference of 23.36.

Table 4.22.
Post-hoc Test Results of Difference of CR Scores and Total Scores of Summative Written Exam in Different Period of CR Teaching Implementation Status for CP1 Dataset

Dependent variable	(I) Year/ Teaching	(J) Year/ Teaching	Mean difference (I-J)	Std. error	Sig.	95% Confidence Interval	
						Lower bound	Upper bound
CR Score	0 2011-2012	1 2012-2013	1.31	0.69	0.14	-0.30	2.93
		2 2013-2014	-22.05*	0.70	0.00	-23.68	-20.41
	1 2012-2013	2 2013-2014	-23.36*	0.70	0.00	-25.00	-21.72
Summative written exams	0 2011-2012	1 2012-2013	-9.05*	1.13	0.00	-11.71	-6.39
		2 2013-2014	-8.14*	1.15	0.00	-10.83	-5.45
	1 2012-2013	2 2013-2014	0.91	1.15	0.71	-1.79	3.62

* The mean difference is significant at the 0.05 level of significance.

Table 4.23 summarized the ANOVA results for the CP3 dataset. For the CP3 dataset, there was no CR teaching in the year 2014, partial CR teaching in the year 2015, and full CR teaching in the year 2016. The results of the ANOVA showed that the CR scores ($F(2, 1000) = 2042.58$, $p < 0.001$) and total score in the summative written exam ($F(2, 1000) = 149.07$, $p < 0.001$) for Paper 1 and CR scores ($F(2, 1000) = 229.76$, $p < 0.001$) and total score in the summative written exam ($F(2, 1000) = 215.66$, $p < 0.001$) for Paper 2 were significantly different during the three school

years of differences in implementation in CR teaching for the CP3 dataset. This was because the p-values were less than the level of significance value of 0.05.

Table 4.23.
ANOVA Results of Difference of CR Scores and Total Scores of Summative Written Exam in Different Period of CR Teaching Implementation Status for CP3 Dataset

		Sum of Squares	Df	Mean square	F	Sig.
CR Score (Paper 1)	Between groups	363234.94	2	181617.47	2042.58	0.00*
	Within groups	88915.64	1000	88.92		
	Total	452150.58	1002			
Summative written exams (Paper 1)	Between groups	50847.42	2	25423.71	149.07	0.00*
	Within groups	170549.66	1000	170.55		
	Total	221397.08	1002			
CR Score (Paper 2)	Between groups	26125.92	2	13062.96	229.76	0.00*
	Within groups	56854.83	1000	56.86		
	Total	82980.75	1002			
Summative written exams (Paper 2)	Between groups	69275.41	2	34637.70	215.66	0.00*
	Within groups	160610.25	1000	160.61		
	Total	229885.65	1002			

* The mean difference is significant at the 0.05 level of significance.

Post-hoc test results in Table 4.24 using Tukey's test showed that the CR score for Paper 1 in the period of no CR teaching (M = 110.17; SD = 10.80) were significantly higher than for the period of partial CR teaching (M = 64.27; SD = 7.39) and for the period of full CR teaching (M = 83.23; SD = 9.88) by mean differences of 45.90 and 26.94, respectively. Also, CR scores for Paper 1 in the period of full CR teaching (M = 83.23; SD = 9.88) were significantly higher than for the period of

partial CR teaching (*M* = 64.27; SD = 7.39) by a mean difference of 18.96. Total score of summative written exams for Paper 1 in the period of no CR teaching (*M* = 141.54; SD = 13.92) were significantly higher than for the period of partial CR teaching (*M* = 125.39; SD = 11.73) and for the period of full CR teaching (*M* = 127.96; SD = 13.50) by mean differences of 16.16 and 13.59, respectively. Also, total scores of summative written exams for Paper 1 in the period of full CR teaching (*M* = 127.96; SD = 13.50) were significantly higher than the period of partial CR teaching (*M* = 125.39; SD = 11.73) by a mean difference of 2.57. CR scores for Paper 2 in the period of no CR teaching (*M* = 66.83; SD = 6.83) were significantly higher than the period of partial CR teaching (*M* = 61.63; SD = 7.81) by a mean difference of 5.23. CR scores for Paper 2 in the period of full CR teaching (*M* = 74.13; SD = 7.94) were significantly higher than the period of no CR teaching (*M* = 66.83; SD = 6.83) by a mean difference of 5.23. Also, CR score for paper 2 in the period of full CR teaching (*M* = 74.13; SD = 7.94) was significantly higher than the period of partial CR teaching (*M* = 61.63; SD = 7.81) by a mean difference of 12.49.

Table 4.24.
Post-hoc Test Results of Difference of CR Scores and Total Scores of Summative Written Exam in Different Period of CR Teaching Implementation Status for CP3 Dataset

Dependent variable	(I) Year/teaching	(J) Year/teaching	Mean difference (I-J)	Std. error	Sig.	95% confidence interval Lower bound	95% confidence interval Upper bound
CR Score (Paper 1)	0 2013-2014	1 2014-2015	45.90*	0.72	0.00	44.21	47.59
		2 2015-2016	26.94*	0.74	0.00	25.20	28.67
	1 2014-2015	2 2015-2016	-18.96*	0.73	0.00	-20.68	-17.25
Summative written exams (Paper 1)	0 2013-2014	1 2014-2015	16.16*	1.00	0.00	13.81	18.50
		2 2015-2016	13.59*	1.02	0.00	11.19	15.99
	1 2014-2015	2 2015-2016	-2.57*	1.01	0.03	-4.94	-0.19
CR Score (Paper 2)	0 2013-2014	1 2014-2015	5.23*	0.58	0.00	3.88	6.58
		2 2015-2016	-7.27*	0.59	0.00	-8.65	-5.88
	1 2014-2015	2 2015-2016	-12.49*	0.58	0.00	-13.87	-11.12
Summative written exams (Paper 2)	0 2013-2014	1 2014-2015	20.11*	0.97	0.00	17.83	22.38
		2 2015-2016	9.69*	0.99	0.00	7.36	12.02
	1 2014-2015	2 2015-2016	-10.42*	0.98	0.00	-12.73	-8.12

*. The mean difference is significant at the 0.05 level of significance.

The CR scores of students were higher at the period of full CR teaching implementation in the CP1 data set than for the periods of no teaching and partial teaching. The same results were found in the CP3 Paper 2 dataset. On CP3 Paper 1, CR scores of students at the period of full CR teaching were higher than the period of partial teaching but lower than the period of no teaching. This might be because of the better knowledge of these CP3 students' cohort that was obvious in their total scores on both Paper 1 and Paper 2. With these results, the null hypothesis for RQ2 (that there would not be a significant effect on students' CRs as a result of CR teaching/implementation) was rejected. The result of the independent sample *t*-test showeda significant effect. This supported the hypothesis that the students with full CR teaching would show more positive results.

4.3.4. Impact of Gender on CR

Quantitative RQ4 asked: "Does gender influence outcomes as measured by summative written exams?"

$H0_4$: There is no significant effect from gender on outcomes as measured by CR score in the summative written exams.

Ha_4: There is significant effect from gender on outcomes as measured by CR score in the summative written exams.

An independent sample *t*-test was conducted to determine whether the gender influence outcomes as measured by the CR score in the summative written exam. Also, different analyses were conducted on the dataset of CP1 and CP3. A level of significance of 0.05 was also used in the independent sample *t*-test.

Table 4.25 summarizes the results of the independent samples *t*-test for the difference of the CR score in the summative written exams by gender in the dataset of CP1. The results of independent sample *t*-test showed that CR scores of the

summative written exam (t (1016) = -1.75, p = 0.08) were not significantly different between males and females. This was because the p-value was greater than the level of significance value of 0.05.

Table 4.26 summarizes the results of the independent samples t-test for the difference of the CR score in the summative written exams by gender in the dataset of CP3. The results of independent sample t-test also showed that CR scores of the summative written exam in paper 1 (t (997) = 0.99, p = 0.32) and paper 2 (t (997) = 0.15, p = 0.88) were both not significantly different between males and females. This was because the p-values were greater than the level of significance value of 0.05. With this result, the null hypothesis for RQ3 (that there would not be a significant effect of gender on outcomes as measured by summative written exams) was accepted.

Table 4.25.
Independent Sample T-Test Results of CR Scores by Gender for CP1 Dataset

		Levine's Test for equality of variances		t-test for equality of means					95% confidence interval of the difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
CR score	Equal variances assumed	0.004	0.95	-1.75	1016	0.08	-1.54	0.88	-3.27	0.19

Table 4.26.
Independent Sample T-Test Results of Difference of CR Scores of the Summative Written Exam Between Two Different Periods of No CR Teaching in Year 2012 for CP1 Dataset and Year 2014 CP3 Dataset

		Levine's Test for equality of variances		t-test for equality of means					95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
CR score	Equal variances assumed	0.51	0.48	0.99	997	0.32	1.35	1.36	-1.32	4.01

4.3.5. Impact of Educational Level on CR Performance

Quantitative RQ5 asked: "Do graduate entry PBL students receive better CR score than UG integrated students?"

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP1

$H0_5$: There is no significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

Ha_5: There is a significant difference in CR score between graduate entry PBL students and UG integrated students at CP3

4.3.5. Analysis of Effect of Curricular Model

An analysis was conducted to investigate different student cohorts from CP1 and CP3 to see how they developed their CR according to their curricular model. It should be noted that CP1 2012 students became CP3 in 2014, CP1 2013 became CP3 in 2015, and CP1 2014 became CP3 in 2016. This was a longitudinal comparison to determine differences in curricular model of: CP1 2012 against CP3 2014, CP1 2013 against CP3 2015, and CP1 2014 against CP3 2016.

Period 1: No implementation of CR curriculum. Figure 4.3 represents a graphical comparison of the CR marks of PBL and integrated students in CP1 2012 dataset. These were the students who had no exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores (t (190.30) = -2.45, p = 0.01) were significantly different between the PBL and integrated students in the CP1 2012 dataset or students who had no exposure to CR curriculum. This was because the *p*-value was less than the level of significance value. Mean comparison showed

that the CR scores of the PBL who had no exposure to CR curriculum (*M* = 59.98) were significantly higher than the integrated students who had no exposure to CR curriculum (*M* = 57.03) in the CP1 2012 dataset by a mean difference of 2.35.

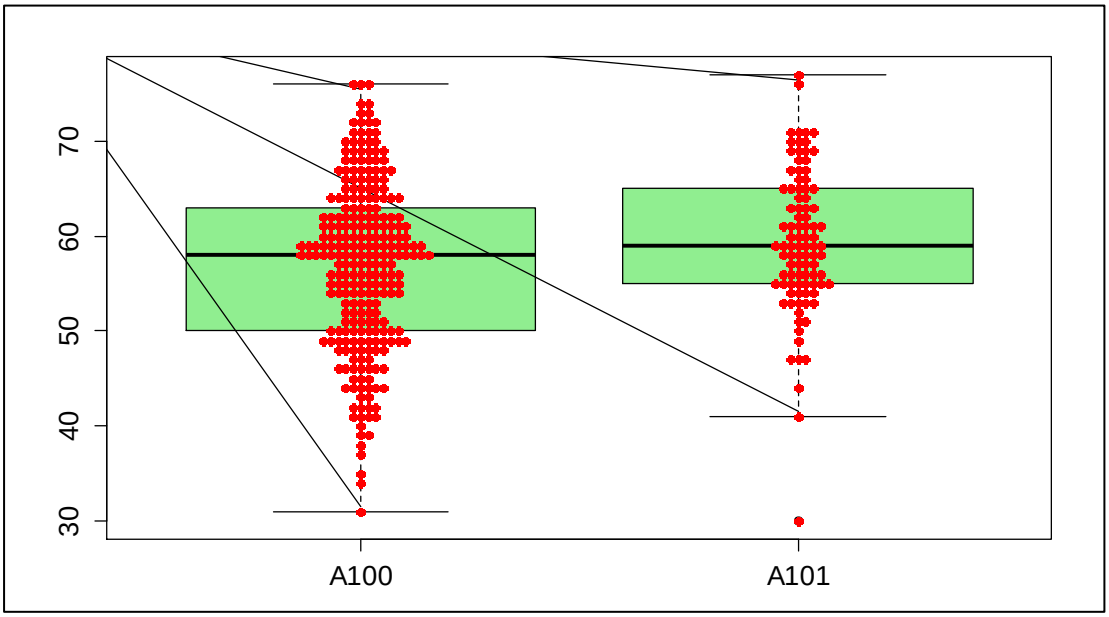


Figure 4.3. Period 1: No implementation of CR curriculum.

Figure 4.4 shows a graphical comparison of the CR marks on Paper 1 of PBL and integrated students in the CP3 2014 dataset. These were also students who had no exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores on Paper 1 ($p = 0.72$) were not significantly different between the PBL students (*M* = 108.06) and integrated students (*M* = 110.91) who had no exposure to CR curriculum in the CP3 2014 dataset. This was because the *p*-value was greater than the level of significance value.

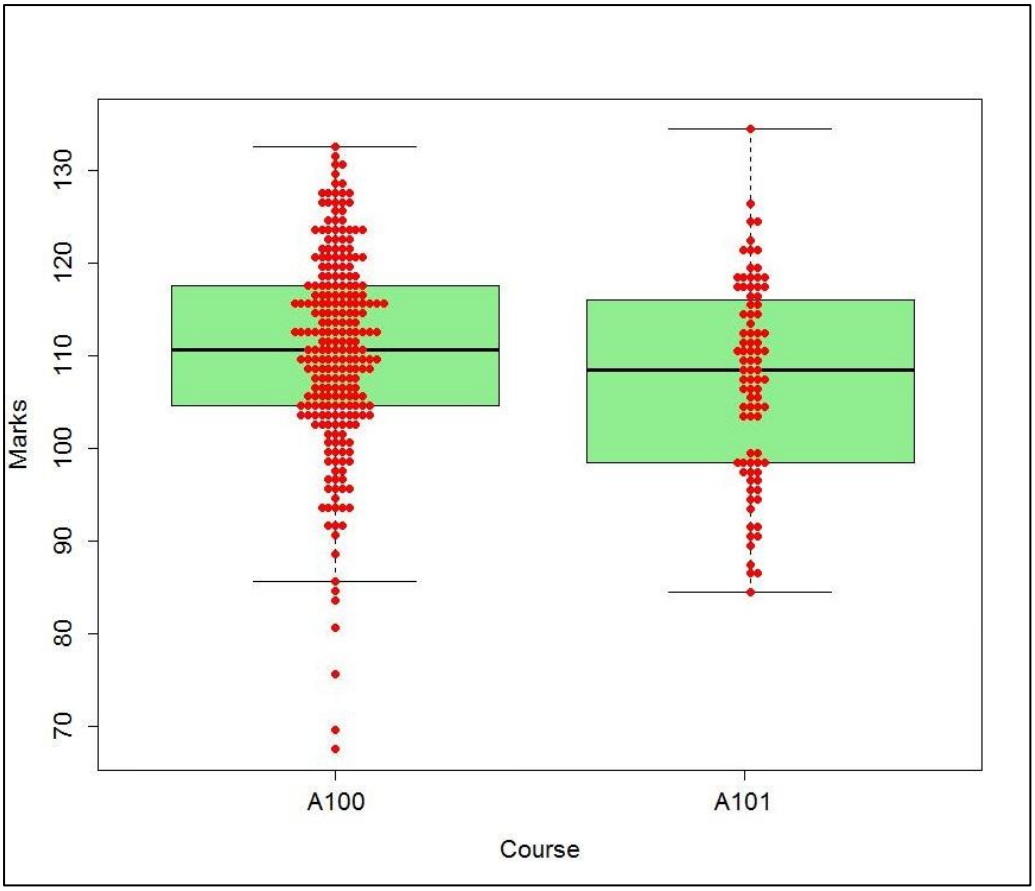


Figure 4.4. CR scores in Paper 1 of integrated (A100) and PBL students (A101) in Year 2014 CP3 Dataset (no exposure to CR curriculum).

Figure 4.5 provides a graphical comparison of the CR marks on Paper 2 for PBL students and integrated students in CP3 2014 dataset. CR. These were also students who had no exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores in paper 2 ($p = 0.72$) were also not significantly different between the PBL students ($M = 64.19$) and integrated students ($M = 67.8$) who had no exposure to CR curriculum in the CP3 2014 dataset. This was because the *p*-value was greater than the level of significance value.

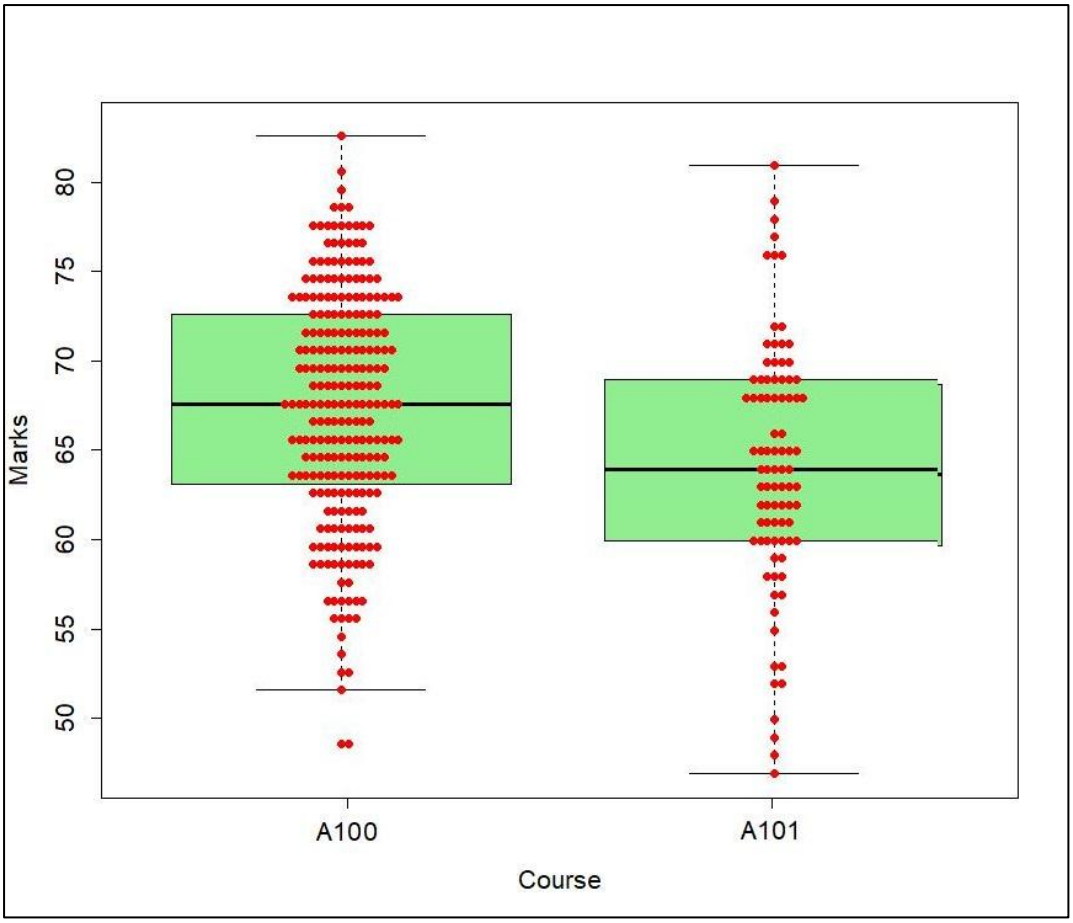


Figure 4.5. CR scores in Paper 2 of integrated (A100) and PBL students (A101) in year 2014 CP3 Dataset (no exposure to CR curriculum).

Period 2: Partial Implementation of CR Curriculum. Figure 4.6 shows a graphical comparison of the CR marks of PBL students and integrated students in CP1 2013 dataset. These were the students who had partial exposure to CR curriculum. The results of the independent sample *t*-test showed that both the CR scores (t (170.12) = 2.97, p = 0.003) were significantly different between the PBL students and integrated students in the CP1 2013 dataset or student who had partial exposure to CR curriculum. This was because the *p*-value was less than the level of significance value. Mean comparison showed that the CR scores of the PBL students who had partial exposure to CR curriculum were significantly higher (M = 58.06) than the integrated students who had partial exposure to CR curriculum (M = 55.77) in the CP1 2013 dataset by a mean difference of 2.28.

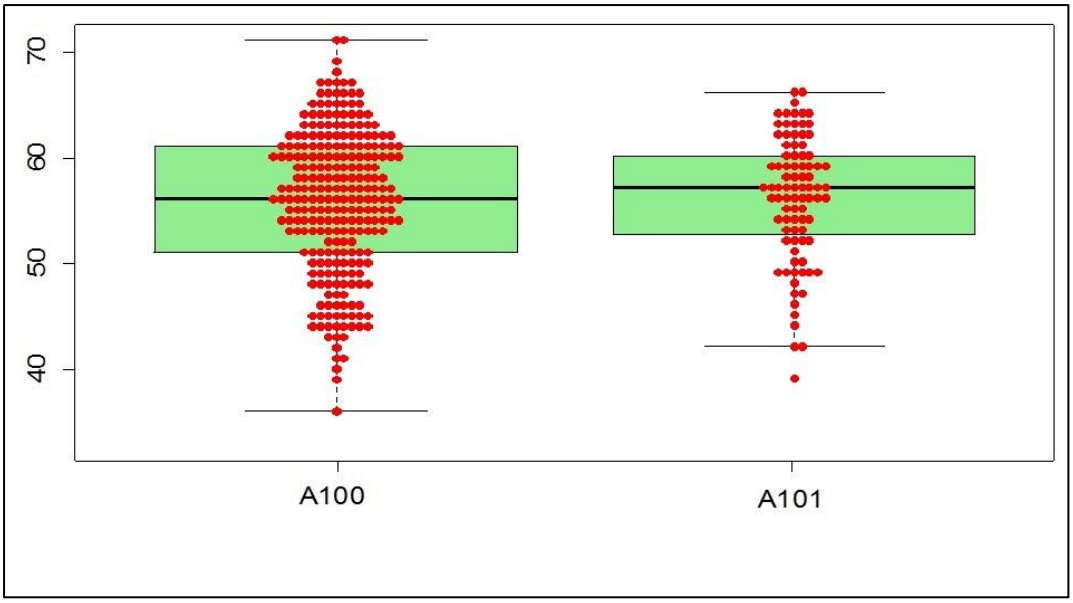


Figure 4.6. CR scores of integrated (A100) and PBL (A101) in year 2012 CP1 Dataset (partial exposure to CR curriculum).

Figure 4.7 shows a graphical comparison of the CR marks on Paper 1 for PBL students and integrated students in the CP3 2015 dataset. These were also students who had partial exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores in paper 1 (t (173.55) = -1.05, p = 0.30) were not significantly different between the PBL students (M = 63.60) and integrated students (M = 64.50) who had partial exposure to CR curriculum in the CP3 2015 dataset. This was because the *p*-value was greater than the level of significance value.

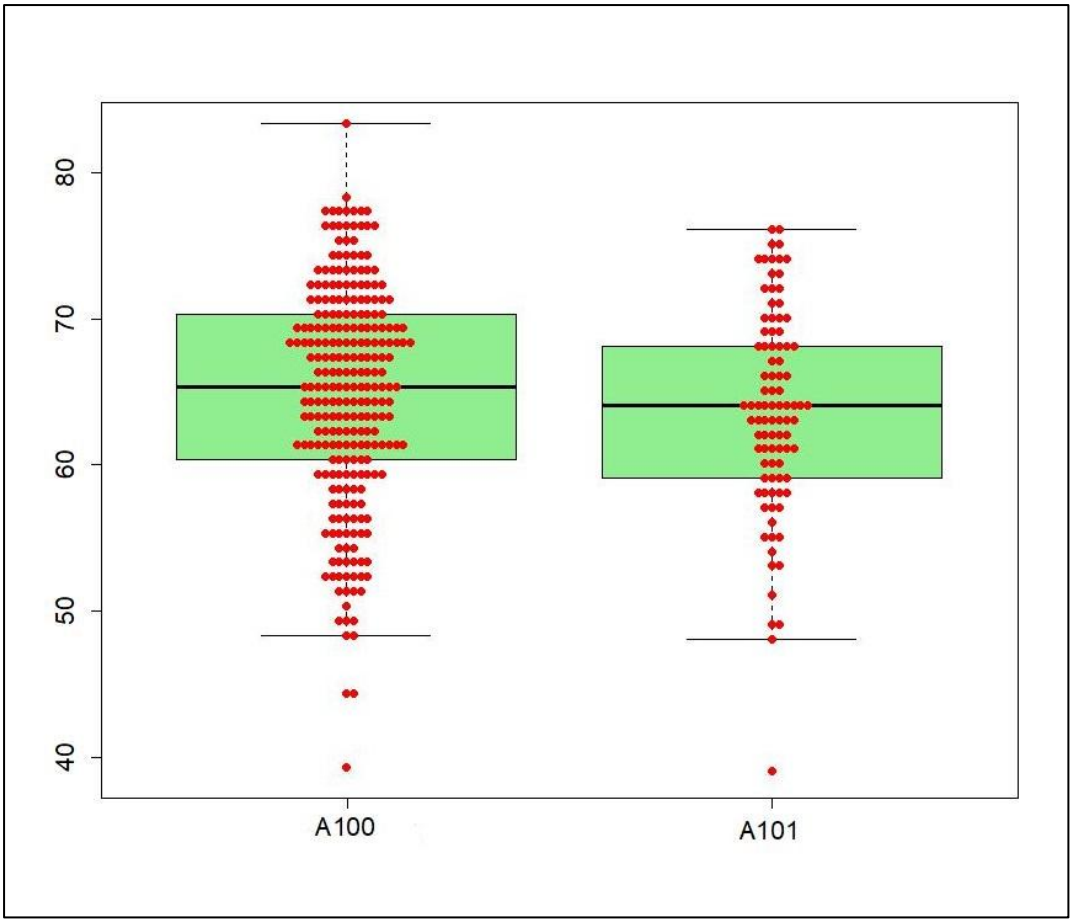


Figure 4.7. CR scores in Paper 2 of integrated (A100) and PBL students (A101) in year 2015 CP3 Dataset (partial exposure to CR curriculum).

Figure 4.8 shows a graphical comparison of the CR marks on Paper 2 of PBL students and integrated students in the CP3 2015 dataset. These were also students who had partial exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores in paper 2 (t (160.81) = -1.80, p = 0.07) were not significantly different between the PBL students (M = 60.37) and Integrated students (M = 62.08) who had partial exposure to CR curriculum in the CP3 2015 dataset. This was because the *p*-value was greater than the level of significance value.

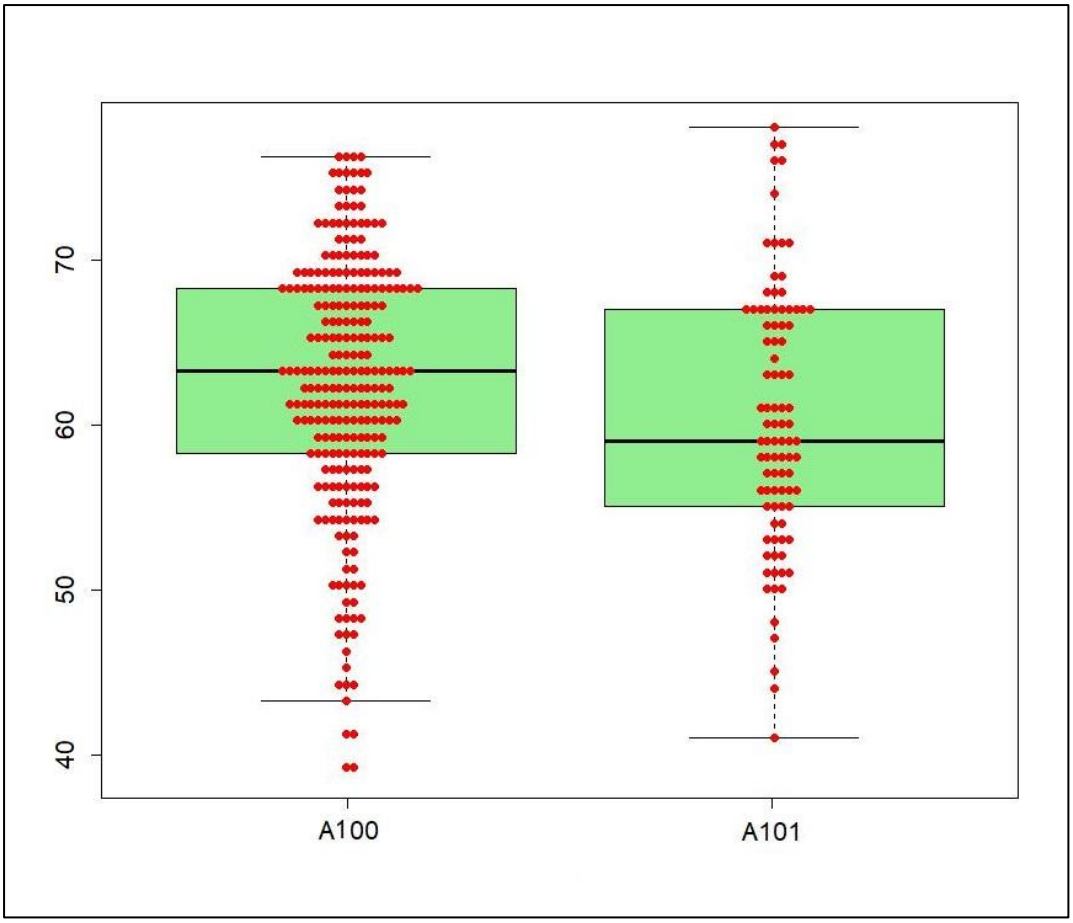


Figure 4.8. CR scores of integrated (A100) and PBL (A101) students in year 2015 CP3 Dataset (partial exposure to CR curriculum).

Period 3: Full Implementation of CR Curriculum. Figure 4.9 shows a graphical comparison of the CR marks of PBL students and integrated students in the CP1 2014 dataset. These were the students who had full exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores (t (164.45) = -2.48, p = 0.01) were significantly different between the PBL students and Integrated students in the CP1 2014 dataset or student who had full exposure to CR curriculum. This was because the *p*-value was less than the level of significance value. Mean comparison showed that the CR scores of the PBL students who had full exposure to CR curriculum (M = 82.16) were significantly higher than the integrated students who had full exposure to CR curriculum (M = 78.92) in the CP1 2014 dataset by a mean difference of 3.25.

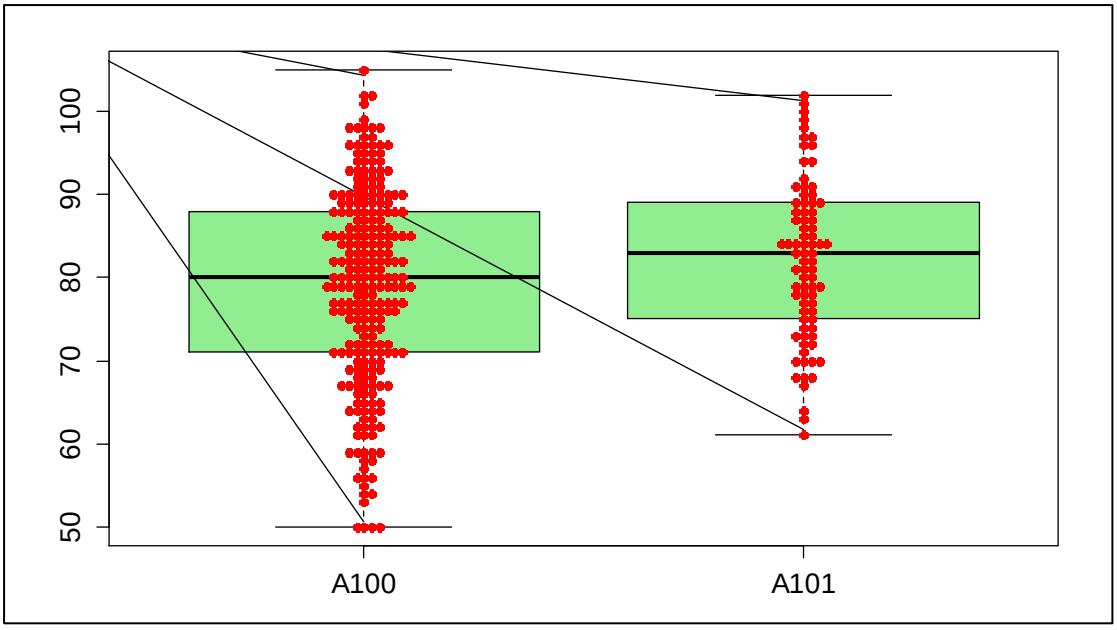


Figure 4.9. CR scores of integrated (A100) and PBL students (A101) in year 2014 CP1 dataset (full exposure to CR curriculum).

Figure 4.10 provides a graphical comparison of the CR marks on Paper 1 of PBL students and integrated students in the CP3 2016 dataset. These were also students who had full exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores in paper 1 (t (133.94) = -1.48, p = 0.14) were not significantly different between the PBL students (M = 81.83) and integrated students (M = 83.66) who had full exposure to CR curriculum in the CP3 2015 dataset. This was because the *p*-value was greater than the level of significance value.

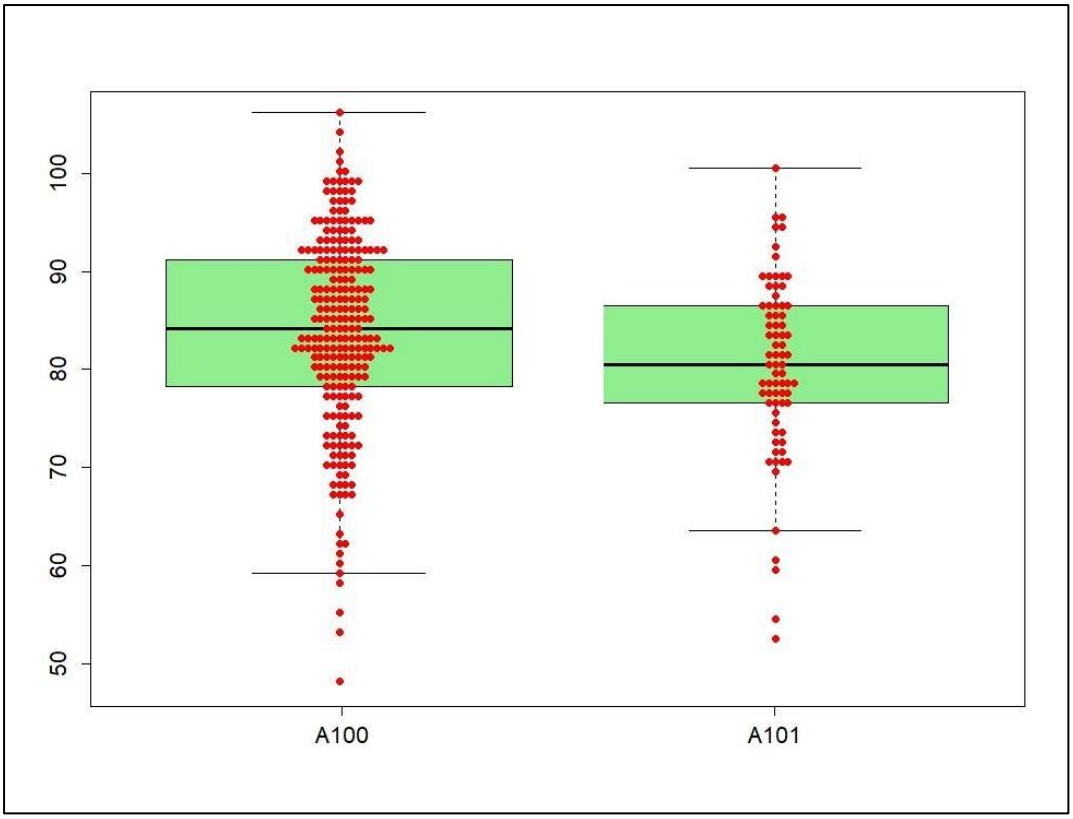


Figure 4.10. CR scores in Paper 1 of integrated (A100) and PBL students (A101) in year 2016 CP3 dataset (full exposure to CR curriculum).

Figure 4.11 shows a graphical comparison of the CR marks on Paper 2 of PBL students and integrated students in the CP3 2016 dataset. These were also students who had full exposure to CR curriculum. The results of the independent sample *t*-test showed that the CR scores in paper 2 (t (121.36) = -2.01, p = 0.05) were significantly different between the PBL students and integrated students who had full exposure to CR curriculum in the CP3 2015 dataset. This was because the *p*-value was less than the level of significance value. Mean comparison showed that the CR scores of the PBL students who had full exposure to CR curriculum (M = 72.51) were significantly lower than the integrated students who had full exposure to CR curriculum (M = 74.63) in the CP3 2016 dataset by a mean difference of 2.21.

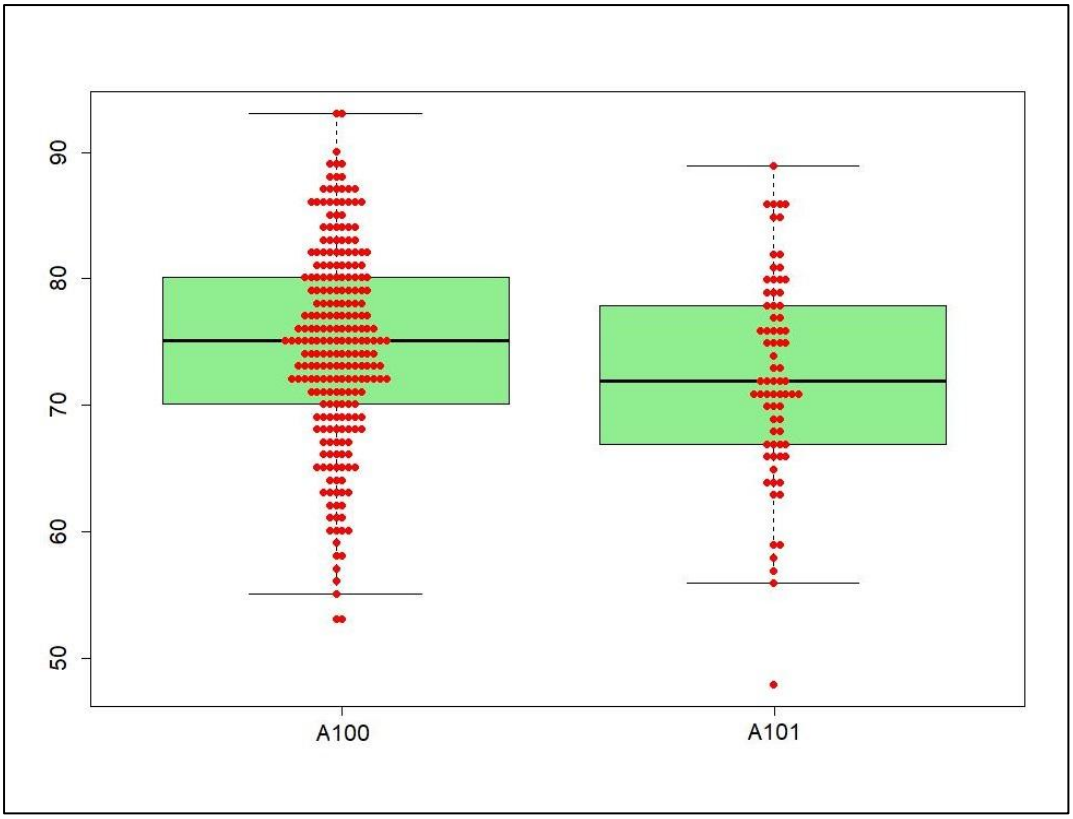


Figure 4.11. CR scores in Paper 2 of integrated (A100) and PBL students (A101) in year 2016 CP3 dataset (full exposure to CR curriculum).

It can be observed that all PBL students scored significantly better than integrated students on the CR component of the summative exam in the CP1 dataset in the three periods of no exposure to CR curriculum, partial exposure to CR curriculum, and full exposure to CR curriculum. This indicated a possible curriculum difference. Mean comparison differences of the CR scores in each of the three periods for the CP1 dataset varied because of the differences in the number CR questions. With these results, the null hypothesis for RQ4 (that there would not be a significant difference in CR score between graduate entry PBL students and UG integrated students at CP1) was rejected.

It was observed that there no significant difference in the CR scores between the PBL students and integrated students in the CP3 dataset. On all papers, integrated students score higher than PBL students, thought not statistically significantly from

CP3 2016 Paper 2. On CP3 2016 Paper 2, integrated students scored significantly better than PBL students on the CR component of the summative exam. This meant that the integrated students in the CP3 dataset caught up in the improvement of CR scores. With these results, the null hypothesis for RQ4 (that there would not be a significant difference in CR score between graduate entry PBL students and UG integrated students at CP3) was accepted. Results showed no effect of curricular difference in CP3 level.

4.3.6. Analysis of Effect of the Curricular Phase

Quantitative RQ4 asked: "Does the curricular phase of the curriculum have an impact on the development of CR?"

$H0_1$: There is no significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

Ha_2: There is a significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams.

An independent sample *t*-test was conducted to determine whether the outcomes as measured by the CR scores in the summative written exams were significantly different in the each of the three periods between the CP1 and CP3 dataset. For instance, year 2012 CP1 students were the same as the year 2014 CP3 students. This longitudinal analysis was conducted to determine how CP1 developed CR to CP3. A level of significance of 0.05 was used in the independent sample *t*-test.

Table 4.27 summarizes the independent sample *t*-test results of the difference in the CR scores in the summative written exams in the period of no CR teaching between the CP1 dataset in the year 2012 and CP3 dataset in the year 2014. The results of the independent sample *t*-test showed that the CR scores (t (636.93) = -70.31, $p < 0.001$) were significantly different in the two different periods of no CR

teaching for the CP1 and CP3 datasets. This was because the p-values were less than the level of significance value of 0.05. Mean comparison showed that the CR scores of the periods of no CR teaching were significantly higher in the year 2014 of the CP3 dataset (M = 110.17; SD = 10.80) than in the year 2012 of the CP1 dataset (M = 57.66; SD = 8.58) by a mean difference of 52.50.

Table 4.28 summarizes the independent sample t-test results of the difference in the CR scores in the summative written exams in the period of partial CR teaching between the CP1 dataset in the year 2013 and CP3 dataset in the year 2015. The results of the independent sample t-test showed that the CR scores (t (692) = -14.76, p < 0.001) on the summative written exams were significantly different in the two different periods of partial CR teaching for the CP1 and CP3 datasets. This was because the p-values were less than the level of significance value of 0.05. Mean comparison showed that the CR scores of the periods of partial CR teaching were significantly higher in the year 2015 of the CP3 dataset (M = 64.79; SD = 7.38) than in the year 2013 of the CP1 dataset (M = 56.32; SD = 6.73) by a mean difference of 7.92.

Table 4.29 summarizes the independent sample t-test results of the difference in the CR scores in the summative written exams in the period of full CR teaching between the CP1 dataset in the year 2014 and CP3 dataset in the year 2016. The results of the independent sample t-test showed that the CR scores (t (643.13) = -4.17, p < 0.001) on the summative written exams were significantly different in the two different periods of full CR teaching for the CP1 and CP3 dataset. This was because the p-values were less than the level of significance value of 0.05. Mean comparison showed that the CR scores of the periods of full CR teaching were significantly higher

in the year 2016 of the CP3 dataset (M = 83.22; SD = 9.89) than in the year 2014 of the CP1 dataset (M = 79.71; SD = 11.41) by a mean difference of 3.51.

Table 4.27.
Independent Sample T-Test Results of Difference of CR Scores of the Summative Written Exam Between Two Different Periods of No CR Teaching in Year 2012 for CP1 Dataset and Year 2014 for CP3 Dataset

		Levine's Test for equality of variances		t-test for equality of means					95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
CR score	Equal variances assumed	13.69	0.00	70.31	636.93	0.00*	-52.50	0.75	-53.97	-51.04

*Significant difference at the 0.05 level of significance.

Table 4.28.
Independent Sample T-Test Results of Difference of CR Scores of the Summative Written Exam Between Two Different Periods of Partial CR Teaching in Year 2013 for CP1 Dataset and Year 2015 for CP3 Dataset

		Levine's Test for equality of variances		t-test for equality of means					95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
CR score	Equal variances assumed	2.30	0.13	14.76	692.00	0.00*	-7.92	0.54	-8.97	-6.86

* Significant difference at the 0.05 level of significance

Table 4.29. *Independent Sample T-Test Results of Difference of CR Scores of the Summative Written Exam Between Two Different Periods of Full CR Teaching in Year 2014 for CP1 Dataset and Year 2016 for CP3 Dataset*

		Levine's Test for equality of variances		t-test for equality of means					95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
CR score	Equal variances assumed	8.85	0.00	4.17	634.13	0.00*	-3.51	0.84	-5.16	-1.85

* Significant difference at the 0.05 level of significance.

In summary, the CR scores of summative written exams of students at the period of no CR teaching implementation were significantly higher in the CP3 dataset than in the CP1 dataset. The CR scores of summative written exams of students at the period of partial CR teaching implementation were significantly higher for the CP3 dataset than for the CP1 dataset. The CR scores of summative written exams of students at the period of full CR teaching implementation were significantly higher for the CP3 dataset than for the CP1 dataset. With these results, the null hypothesis for RQ5 (that there would not be a significant effect in CR score from the curricular phase on outcomes as measured by CR score in the summative written exams) was rejected. CP3 students scored higher than CP1, which supported the statement that CR was improved and developed from CP1 to CP3.

CHAPTER 5 DISCUSSION OF RESULTS

In this chapter, the researcher discusses and interprets the results of the data analysis. The first section encompasses the discussion of the qualitative and quantitative findings, framed by the literature and the theoretical framework. The second and third sections provide discussion of the recommendations for future research and practice. In the last section, the researcher offers conclusions from the study.

5.1 DISCUSSION OF THE FINDINGS

The main focus of this study was answering the questions: “How is CR being embedded in the UG curriculum at the University of Nottingham?” To that end, the researcher monitored all of the planning processes, implementation decisions, and creation of evaluation tools for measuring how effectively the curriculum elements achieved the CR goals. The UoN CR curriculum is dynamic, with the researcher maintaining involvement in efforts to change some of the CR components, while other changes occurred without intervention. This study followed a moving target to identify the where and how CR curriculum changes were taking place.

Because of our new intervention, UoN BMedSci is changed into more of an integrated course with more clinically relevant experience, case studies and a patient centred approach along with an increased focus on dissection studies. The changes were not necessarily content changes, but were re-orderings and re-badgings according to each week’s themes or cases. The science component of the BMedSci was not dropped, but was reinforced by an increase in the CR activity. Implementation began in 2017, with the GEM course and its CR components still continuing as of Month 03, 2019. The main focus of this study was answering the question: “How is CR being embedded in the UG curriculum at the University of

Nottingham?" As noted above, UoN BMed Sci is changed into more clinically relevant one. CR teaching for clinical years and clinical teachers training were implemented. These are the evidence that CR is embedded vertically throughout UoN UG curriculum. The final CR curriculum document for the students is attached in Appendix 4. The curriculum document signposts places where CR is embedded and how it is linked to the existing programme. Mapping this vertical curriculum and identifying which element is explicit and which is implicit in the final curriculum model shows CR where it is embedded.

It was not possible to perform a comparison before and after implementation of the new curriculum. The new curriculum could not be evaluated after five years and could not be compared to a study of the original curriculum in order to evaluate the differences. The researcher was presented with an opportunistic situation when the decision was made to introduce a CR strand into the curriculum, at which point the research determined to evaluate the development and effectiveness of the strand during the implementation phase. Curriculum effectiveness was measured in two aspects: (a) the degree to which participants found the learning engaging and favourable, and (b) the degree to which participants acquired the intended knowledge and skills.

During iterative development of the curriculum, evaluation of the curriculum took place. The researcher designed evaluations of CR, acquired evaluation data for them, reviewed the educational interventions, and helped to redesign the course.

5.1.1. Discussion of Qualitative Interview Results

For the first thematic category of ("Understanding and meaning of CR"), all of the students were familiar with the term CR, but they were uncertain about its various components. This suggested general knowledge of the essence of the term, but

somewhat poor understanding of CR as a conceptual term. Among the teachers, most of the participants affirmed that CR was a cognitive process underlying decision-making and key to diagnosing in healthcare.

The literature supported the seemingly confused understanding of the participants regarding CR. For instance, Da Silva (2015) stated that the definitions of CR are varied and often lack a necessary consensus, while some components are commonplace among various studies. Generally, the participants in the study subscribed to the common definition that CR is a thinking process through which a doctor manifests his/her ability to make clinical decisions based on the clinical information that is made available to him/her through experiences in the profession (Holyoak & Morrison, 2012). Although CR is an important component of competent medical practice, there was little agreement on what CR is reflected in either the current literature or this current study.

For the second thematic category ("Importance of CR"), both students and teachers acknowledged that CR was very important for them. Among students, the importance attributed to CR was based on the belief that it is a fundamental skill and needed for efficient practice. Teachers expressed the belief that CR was very important only because it was the main function of a doctor.

The literature supported the importance of CR in clinical practice. For instance, CR has been found to be a core ability to be mastered during training and refined throughout career. It is well known in medical education that an adequate knowledge base is key for making clinical decisions (Durning et al., 2013; Kogan & Hlomboe, 2015). The results of the current research study suggested that both students and teachers recognized CR's importance in clinical practice, despite incomplete understanding of the concept.

For the third thematic category ("Differences in Curricular Models"), all the fifth-year integrated students believed that PBL students were better in CR. Among teacher participants, many fellows revealed that PBL students show more logical thought processes and step-wise reasoning abilities and may spot problems that the non-PBL students would not consider. There is literature support for the superiority of PBL curriculum compared to traditional curriculum. For instance, Patel et al. (1991) found that the PBL curriculum may facilitate the development of inductive reasoning in students. PBL students also produced higher quality explanations using biomedical information, which can be a sign of a better ability to integrate new knowledge (Patel et al., 1991). These results were also supported by Hmelo (1998), who found that PBL curriculum fostered students' abilities to provide more integrated and complex explanations and their ability to transfer reasoning strategies across learning environments

For the fourth thematic category ("Opportunities for CR learning"), some students said that CR was not taught, while other students said that they did receive teaching on CR. Some noted CR teaching is acquired experientially even in the absence of formal teaching. The students also expressed barriers to learning CR including: content factors, environmental factors, and teacher factors. Teachers said that CR was not specifically taught at UoN because of institutional barriers.

The literature supported the presence of barriers in the learning or acquisition of CR. For instance, there are many challenges and barriers to teach CR that Ledford and Nixon (2015) summarized, which included content factors, environmental factors, and expertise factors. The lack of faculty expertise in teaching CR remains a significant barrier (Eva, 2005). Even if there is an outstanding educational programs for CR, efforts will be compromised if faculty are not prepared to teach it (DaRosa et

al., 2012). The results of the current study underscored the continued presence of different barriers in the development and teaching of CR.

For the fifth thematic category ("Process of learning CR"), many students from the integrated curriculum did not feel there was much development of CR in preclinical years, but some found it useful as a foundation for the first years of learning. Teachers shared that they developed their CR through exposure to many patients in the wards during their actual practice. The literature supported the importance of clinical experience in the development of CR. Despite the importance of knowledge in clinical problem solving, applying this knowledge in practical settings is even more important. Experience with real patients is essential for developing connections between the learned material and clinical presentations. Mamede and Schmidt (2004) stated that practice alone, opportunistically, would lead to exposure to a bigger pool of cases and therefore an increase in the number of illness scripts or case templates used to match and solve new cases.

For the sixth thematic category ("Curricular improvements"), students recommended an earlier emphasis on CR and more exposure to lectures and simulation activities in pre-clinical training. During clinical years, different forms of case-based interventions are believed to improve their CR development, including symptom-based teaching, simulation, and hands-on practice with real patients. Teacher participants suggested central teaching should emphasize CR throughout the educational continuum and the use of role modelling.

The literature supported the use of the various suggestions that the participants recommended for improving CR. Even though simulation activities have been used, the ability to correctly identify aspects of a learner's performance with direct observation can be more effective (Holmboe, 2004). With regard to the suggestion of

teachers for modelling, the more knowledge is organised in a structure way, for example using a mind map, the more it would result in efficient CR and diagnostic success (Bordage, 1994). While educational techniques that have been proven to improve CR are well explored in the literature, the lack of faculty expertise in teaching CR remains a significant barrier (Eva, 2005). This suggested that these recommended improvements need to be translated into actual knowledge from teachers during the delivery of the curriculum in order to be feasible.

For the seventh thematic category ("Assessment of CR"), participants disagreed regarding the nature of CR assessment they have received. Some students did not think CR is assessed whereas some supposed there were some questions that assessed CR across all the clinical years. Like students, teachers were not in agreement regarding CR assessment. Some clinical teachers admitted that they have not seen the knowledge papers yet. Some fellows were not sure whether CR can be assessed or not at UG levels in the exam settings.

The literature supported the difficulty of assessing CR among students. CR has been rarely taught in medical schools in formal teaching formats (Felix et al., 2015). Additionally, there has been no clear consensus formed regarding the best methods of teaching or assessing CR (Durning et al., 2013). CR, like other high-order cognitive processes, is not accessible through direct observation and must be assessed indirectly by measuring its end products or via individual verbalisation as inference (Patel et al., 2005).

5.1.2 Discussion of Quantitative Results

Quantitative RQ1 asked: "Does the participation in CCS CR teaching curriculum model influence outcomes as measured by summative written exams?" The results of the statistical analysis indicated that that there was a significant effect

from the participation in CCS CR teaching. Although there was some significant effect from the participation in CCS CR teaching curriculum model on outcomes, it did not necessarily mean that the students who participated in CCS CR teaching curriculum model would achieve higher scores than who did not participate.

These findings can be supported by the literature, underscoring the importance of formal curriculum in the development of CR among students. Although, multiple studies have been conducted to examine the effect of the curriculum on CR, its role in enhancing the development of CR skills in medical students is still not well understood (Patel 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 CR. This study's findings support the effectiveness of exposure to curriculum in CR enhancement among students.

Quantitative RQ2 asked: "Does the redesign of the course each year improve the performance of CR curriculum?" The results of the statistical analysis indicated that there was a significant effect from CR teaching/implementation process on students' CR. This supported the hypothesis that the students with full CR teaching show more positive results.

These findings about the significance of the redesigning of courses supported Ericsson's (2006) theory of deliberate practice, highlighting the timely feedback, coaching, and effortful practice required for achieving a better performance. This not only means that practice has to be intentional and not opportunistic, but that it has to be planned, evaluated and redesigned based on identified learning needs. It also must represent a challenge.

Quantitative RQ3 asked: "Does gender influence outcomes as measured by summative written exams?" The results of the data analysis revealed no significant

difference between males and females in terms of outcomes as measured by summative written exams. The current study supports the results of studies, Ashoorion, V., Liaghatdar, M. & Adibi, P. 2012, Anderson, 2006, Staff, 2014, Shafaroodi, Kamali, & Parvizy, 2014, Da Silva, 2013 revealing no gender differences in the CR of men and women.

Quantitative RQ4 asked: "Do graduate entry PBL students receive better CR score than UG integrated students?" The analysis revealed no significant difference in CR scores between graduate entry PBL students and UG integrated students at CP3. These findings showed that there were no effects of curricular difference at the CP3 level.

These findings suggested that PBL and integrated curricula were relatively the same in terms of influencing CR skills among students. This was contrary to the findings of Brauer and Ferguson (2015), who argued that integrated curriculum was more beneficial for the teachers and students since it allows them to integrate a variety of concepts that had more relevance to the practical life of students. Despite studies proving the superiority of one curriculum over others, there would still be other factors influencing the development of CR (Norman & Eva, 2003). These authors emphasized that the research agenda should analyse specific aspects of PBL on defined variables rather than only focusing on the curriculum as a whole. It appears as long as there was exposure to CR development during training, CR was enhanced.

For the analysis of CR scores in summative exams, quantitative RQ5 asked: "Does the curricular phase of the curriculum have an impact on the development of CR?" The results of the analysis indicated that there was a significant effect in CR scores from the curricular phase on outcomes as measured by CR score in the

summative written exams. CP3 students scored higher than CP1 students, supporting the statement that CR improved and developed from CP1 to CP3.

These findings supported the literature conclusions that the phase of curriculum had an impact on CR development. The studies of Hmelo (1998), Koh et al (2008) and Norman and Schmidt (2000) also revealed that the clinical phase of the curriculum had a strong impact on students' CR. Good clinical skills such as communication skills were vital in light of the fact that the heart of CR is often patient history and physical examinations (Windish et al., 2005).

5.1.3 Discussion of how the qualitative and quantitative findings support each other

Quantitative findings predominantly addressed CR in summative assessments, with qualitative findings having more to do with students' attitudes toward a variety of CR developments. The findings from the qualitative study could be used as a learning needs assessment, contributing to further development and changing educational practice. Knowing what learning opportunities helped students served to assist faculty with decide what strategies should be adopted.

In a qualitative study, it has been concluded that medical students in the UoN perceived PBL students as having better CR skills than their peers in integrated courses at the start of CP1. Interestingly, however, the difference was minimal at the end of CP3. The quantitative portion of the study also sought to determine whether there were any significant differences in CR skills between the students undertaking PBL and the integrated course, measured by the results of summative exams after CP1 and CP3. These quantitative results echoed the finding that qualitatively measured the self-perceived CR skills of PBL and integrated medical students at the CP1 and CP3 levels.

Numerous tools for assessing CR skills are present in literature. However, since no single, gold-standard, complete assessment method has been identified, a multisource and broad approach is recommended for assessing CR in medical students. In the qualitative portion of this study, medical students and TFs were interviewed regarding their views on whether CR was assessed in their summative knowledge papers. Generally, opinions were divided. Students who agreed that CR was assessed had different opinions on the degree of CR involved in the examinations. Interviewees who did not think CR was assessed held their views due to their interpretation of CR assessment, the difficulty of measuring CR skills due to the complex nature of the CR process, and the limitations of the knowledge papers. However, the unique aspect of this quantitative study was the use of multipurpose standardized assessment tools – in this case, summative written exam papers. The papers facilitated assessment across a predetermined set of problems, allowing for sampling from a broad set of content domains within limited testing time.

5.2 LIMITATIONS

The overall methodology used in this study had limitations. The first limitation was the inability of to use conventional evaluation methodology to compare the performance of students exposed to the new curriculum as compared to those not exposed to the new curriculum. The limited time and resources hindered the use of the this conventional evaluation methodology. Finally, the study also was limited by the inability of the researcher to compare the five-year curriculum with and without the new CR strand, a process that would take 10 years to complete.

Qualitative interviews did not take place with pre-clinical year teachers, taking place only with TFs. In addition, interviews were limited to TFs from the NUH NHS

trust. The study did not cover the teaching staff from all the other trusts because TFs from the NUH NHS trust can represent other TFs at other trusts.

CP1 and CP2 students were asked for their views regarding the assessment of CR. Although CP3 students knew about their CP1 exams, CP1 students had not yet sat for their exams. Similarly, the CP3 students had not yet sat their CP3 exams. As a result, some of the participants' views were based purely on their formative progress tests and mock OSCEs. Interviews took place before the implementation of new exam patterns, with more research required to confirm the findings.

As previously noted, there is no gold standard for assessing CR. The data in this quantitative chapter were drawn from purely summative knowledge papers as a proxy measure, which means that all of the different aspects of CR were not assessed. Moreover, both CP1 students and CP3 students are required to sit for OSCEs as well as for the summative written exams. The researcher could not analyse the students' OSCE performance, preventing the collection of a richer and more complete dataset. Due to ethical restrictions, involving OSCE data would have needed all OSCE questions and marking scheme to pick up the decision-making marks from the overall marks to compare and breakdown of each student's marks in each station. The scope of the requested data and the time frame it would take to process was not realistic. They were protected examination information and should not readily enter a research domain.

In the quantitative study, the researcher collected many data sets with different numbers of students, different summative knowledge exam papers, and different components of CR marks in each cohort. The researcher conducted an independent sample t-test comparing the group means instead of conducting a pairwise analysis of the difference of scores. The total raw scores reflected the weight of the correct

answers. The possible implication of this limitation is that assumptions of equal variance among the different groups cannot be guaranteed.

The awareness of CR among students and teachers improved after the introduction of the new CR curriculum, but the effectiveness of the curriculum could not be comprehensively measured in this study. Not all variables associated with the implementation of the CR curriculum could be identified, controlled, and measured in the dynamically developing curriculum over the time period studied. However, the effects of CCSs were a small part of the CR curriculum that could be monitored. Only the relationship between participating CCSs and CR marks was measured as part of this quantitative study. In addition, there were many other factors that might affect these findings, including the fact that the students who participated in these CCS CR teachings were the top students. Therefore, future studies should explore the effectiveness of CR at Level 3 and Level 4. In addition, researchers should consider other factors affecting the CR such as the stages of progression in the course/career, domain-specific knowledge, specialty and professional experience, critical thinking, moral development and confidence, emotional intelligence, problem solving, communication skills, and fatigue/illness/ stress/ personality.

5.3. RECOMMENDATIONS FOR FUTURE STUDIES

Future researchers could conduct a quantitative time series study examining the effectiveness of CR teaching curriculum as a way of enhancing students' CR. Specifically, researchers could examine whether levels of CR can be sustained over a specific period of time after being exposed to a CR teaching curriculum. This line of research would determine whether levels of CR are ingrained once acquired through formal education or whether levels decrease over time.

Future researcher also could use other outcome measures in order to determine the effectiveness of CR teaching curricula. The current study measured CR in terms of student performance on written summative exams. Future studies could improve the measurement of outcomes by using standardized instruments and video analysis of OSCEs. CR also could be measured by using patient outcomes as the basis for determining enhancements in CR.

Another recommendation for future research involves examining the difference in CR in terms of the length of students' clinical experiences. Such a study would be useful for determining whether longer exposure to real-life practice yields higher levels of CR. This type of research could extend this study's findings by determining how a CR curriculum can be implemented more effectively during the training of medical students.

Future researchers also could focus scholarship efforts on identifying the important components of an assessment model designed to evaluate the CR level of students. Such research could be framed by exploring the different outcomes that can signal whether a student is demonstrating CR. Future researchers could conduct an exploratory study focused on developing an appropriate rubric for tapping into the different components or aspects of effective CR.

5.4. RECOMMENDATIONS FOR PRACTICE

The researcher first recommends that CR teaching curriculum be used as a way to enhance the CR of students. Even though the literature on the effectiveness of a formal curriculum in developing CR has not been established, this study extends the support for its effectiveness. The clinical training of students should have explicit and implicit CR components designed to enhance students' CR.

Study findings also reveal the wisdom of formulating an assessment plan or rubric that would capture the conceptual components of CR. An effective assessment rubric for CR would facilitate better redesign of courses that would target specific weaknesses based on student outcomes. Assessing students for CR should come from a variety of sources since CR is connected to multiple traits such as knowledge, skills, and problem solving, each of which is best assessed by tool specifically designed to assess that trait (Schuwirtz, 2009).

The researcher also recommends that teachers improve their abilities to provide instruction with regard to CR. Many of the teachers in the study believed they did not have the training and experience necessary for implementing curricular programs intended to enhance the CR of students. Medical schools should have a staff training and development programs designed to enhance the abilities of teachers to successfully enhance their students' CR knowledge and skills.

5.5. CONCLUSIONS

The main finding of the research was that the implementation of a CR teaching curricula can enhance the CR of students. This suggested that CR can be developed before clinical practice. In order to facilitate the effective implementation of a CR curriculum, attention should be given to important aspects such as facilitating factors, removing barriers, training teachers, making effective assessment, and implementing effective strategies for CR development.

This study yielded a finding regarding the lack of gender differences in the CR of male and female students in terms of improvements in their CR levels as a result of exposure to a CR teaching curriculum. These findings demonstrated that curricular modifications may not be necessary to address gender differences in the development of CR.

Most of the findings generated from the qualitative phase of this study confirmed previous literature about different aspects of CR, such as the complexity of the definition of CR, the perceived importance attributed to CR by both students and teachers, the barriers for implementation of CR, the lack of teacher training, and the lack of effective assessment tools. The current study provided convergent evidence about these previous findings. The results of the current study generally confirmed these studies, further strengthening their validity.

This study was part of a dynamic process that over the period from 2011 to 2017. The researcher disseminated the curriculum at many conferences with multi-institutional interest groups. The list of presentations and publications is presented in the frontmatter of this thesis.

During the course of writing this thesis, the GMC released another version of "Outcomes for graduates 2018," vindicating the approaches adopted in this thesis, namely an increased emphasis on the teaching and assessment of CR in the UG curriculum providing more details, and making the requirements more explicit (Appendix 3)

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Appendix 1. Healthy Volunteer's Information Sheet 1

Names, Position, Department, institution and Qualifications of Investigators:

Prof Reg Dennick, Medical Education Unit, Professor of Medical Education, Assistant Director of Medical Education

Dr Swe Khin-Htun Part-time PhD Student, School of Community Health Sciences

Healthy Volunteer's Information Sheet

Invitation paragraph

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 to explore how students learn about clinical reasoning and the curriculum factors that might influence its acquisition and evaluating the effectiveness of an undergraduate Clinical Reasoning Curriculum.

The Medical School in the University of Nottingham introduced a Clinical Reasoning strand into its undergraduate curriculum. Although clinical reasoning skills are acquired by the experiential learning of undergraduates as they pass through the clinical curriculum it has not been formally taught as a specific element in the curriculum. Responding to recommendations on curriculum content from the General Medical Council, the Medical School introduce a vertically integrated clinical reasoning strand starting in year 1 and working its way through the whole 5 years of the curriculum. We propose to take advantage of this development in order to participate in and evaluate the effectiveness of this new curriculum element. The qualitative aspect of this will involve an interview during which the students and clinical teachers will describe their own understanding of clinical reasoning and how they have acquired/taught the skill plus they will be asked to tell us the way we should emphasize to develop clinical reasoning more.

Why have you been chosen?

You are the undergraduate medical student/ the clinical teachers at the University of Nottingham

Do you have to take part?

Taking part in this research is entirely voluntary. If you do decide to take part, please let me have your contact details to swe.khin-htun@nhs.net and we will invite you for interview. If you are not happy to use the data for this project, you are free to withdraw.

What do I have to do?

Just give the time to take part in interview. It will take 30 minutes.

What are the possible disadvantages and risks of taking part?

We have considered any adverse effects of taking part carefully, and none have been identified. This is just the feedback about the new course. The information you reveal in the interviews will be strictly confidential.
Only the investigator and her supervisor will have access to the information recorded. All data will be anonymised and stored on secure password protected servers in the University of Nottingham.

What will happen to the results of the research study?

- A final report with recommendations will be submitted to the Medical School Dean and the MEU
- Dr Swe Yin Khin-Htun will use the project and its findings as the basis of her PhD Thesis.
- Abstracts for oral and/or poster presentations will be submitted to relevant national and international education and research conferences.
- Publication will be sought in a peer reviewed academic journal.

Dr Swe Yin Khin-Htun
Undergraduate Medical Education Fellow
Trent Simulation & Clinical Skills Centre (TSCSC)
Swe.khin-htun@nhs.net

Appendix 2. Ethics Letter

The University of Nottingham

Faculty of Medicine and Health Sciences

Research Ethics Committee
School of Medicine Education Centre
B Floor, Medical School
Queen's Medical Centre Campus
Nottingham University Hospitals
Nottingham
NG7 2UH

Direct line/e-mail
+44 (0) 115 8232561
Louise.Sabir@nottingham.ac.uk

3rd May 2016

Professor Reg Dennick
Professor of Medical Education/Assistant Director
Medicine Education Centre, B Floor
School of Medicine
QMC Campus
Nottingham University Hospitals
NG7 2UH

Dear Professor Dennick

Ethics Reference No: MEU19012016 SoMEC – **please always quote**
Study Title: Developing and Implementing the incorporation of clinical reasoning elements into the undergraduate medical curriculum.
Chief Investigator/Supervisor: Professor Reg Dennick, Professor of Medical Education, School of Medicine Education Centre.
Lead Investigators/student: Dr Swe Khin-Htun, PhD Student, School of Medicine Education Centre.
Type of Study: Educational evaluation, secondary data analysis of anonymous datasets.
Start Date: 1/10/2011 **Proposed End Date:** 30/05/2017
No of Subjects: n/a anonymous datasets

Thank you for your letter dated 19th January 2016 requesting an opinion on whether the proposed analysis of anonymous exam data across the undergraduate curriculum for the presence of clinical reasoning questions requires full research ethics committee approval.

On review this is an educational/service evaluation/secondary data analysis of the assessments of the current undergraduate curriculum and does not require full research ethics review by this Committee. The data already exists, there will no direct contact with participants and the data will be anonymous.

If you wish to publish this you can indicate under "who gave ethical approval" that you have approached the Faculty of Medicine and Health Sciences Research Ethics Committee and they did not consider that this was necessary as it was considered to be an evaluation of pre-existing anonymous data of Medical Education course assessments and in our institution this does not require full research ethics review.

Yours sincerely

pp Louise Sabir

Professor Ravi Mahajan
Chair, Faculty of Medicine & Health Sciences Research Ethics Committee

Appendix 3. The New Version of GMC "Outcomes for Graduate 2018"

The New version of GMC "outcomes for graduate 2018"

Outcomes 1 – Professional values and behaviours

Professional and ethical responsibilities

2. Newly qualified doctors must behave according to ethical and professional principles. They must be able to:

c. summarise the current ethical dilemmas in medical science and healthcare practice; the ethical issues that can arise in everyday clinical decision-making; and apply ethical reasoning to situations which may be encountered in the first years after graduation

j. recognise the potential impact of their attitudes, values, beliefs, perceptions and personal biases (which may be unconscious) on individuals and groups and identify personal strategies to address this

l. explain and demonstrate the importance of: L SEP

providing information about options for investigations, treatment and care in a way that enables patients to make decisions about their own care

s. access and analyse reliable sources of current clinical evidence and guidance and have established methods for making sure their practice is consistent with these

Outcomes 2 – Professional skills

Diagnosis and medical management

12. **Newly qualified doctors must work collaboratively with patients and colleagues to diagnose and manage clinical presentations safely in community, primary and secondary care settings and in patients' homes.**

Newly qualified doctors must, wherever possible, support and facilitate patients to make decisions about their care and management.

14**. Newly qualified doctors must be able to work collaboratively with patients, their relatives, carers or other advocates to make clinical judgements and decisions based on a holistic assessment of the patient and their needs, priorities and concerns, and appreciating the importance of the links between pathophysiological, psychological, spiritual, religious, social and cultural factors for each individual.**

They must be able to:

a. propose an assessment of a patient's clinical presentation, integrating biological, psychological and social factors, agree this with colleague

c. interpret findings from history, physical and mental state examinations

d propose a holistic clinical summary, including a prioritised differential diagnosis/diagnoses and

e propose options for investigation, taking into account potential risks, benefits, cost effectiveness and possible side effects and agree in collaboration with colleagues if necessary, which investigations to select

f interpret the results of investigations and diagnostic procedures, in collaboration with colleagues if necessary

g. synthesise findings from the history, physical and mental state examinations and investigations collaboration with colleagues if necessary, and make proposals about underlying causes or pathology

h understand the processes by which doctors make and test a differential diagnosis and be prepared to explain their clinical reasoning to others

i make clinical judgements and decisions with a patient, based on the available evidence, in collaboration with colleagues and as appropriate for their level of training and experience, and understand that this may include situations of

uncertainty

j take account of patients' concerns, beliefs, choices and preferences, and respect the rights of patients to reach decisions with their doctor about their treatment and care and to refuse or limit treatment

n. recognise the potential consequences of over-diagnosis and over-treatment.

Using information effectively and safely

19 Newly qualified doctors must be able to use information effectively and safely in a medical context, and maintain accurate, legible, contemporaneous and comprehensive medical records.

They must be able to:

a. make effective use of decision making and diagnostic technologies

Outcomes 3 – Professional knowledge

Applying biomedical scientific principles

22 Newly qualified doctors must be able to apply biomedical scientific principles, methods and knowledge to medical practice and integrate these into patient care. This must include principles and knowledge relating to anatomy, biochemistry, cell biology, genetics, genomics and personalised medicine, immunology, microbiology, molecular biology, nutrition, pathology, pharmacology and clinical pharmacology, and physiology.

They must be able to

b. explain the relevant scientific processes underlying common and important disease processes

c justify, through an explanation of the underlying fundamental principles and clinical reasoning, the selection of appropriate investigations for common clinical conditions and diseases

d select appropriate forms of management for common diseases, and ways of

preventing common diseases, and explain their modes of action and their risks from first principles

f. analyse clinical phenomena and conduct appropriate critical appraisal and analysis of clinical data, and explain clinical reasoning in action and how they formulate a differential diagnosis and management plan.

Applying psychological principles

23 Newly qualified doctors must explain and illustrate by professional experience the principles for the identification, safe management and referral of patients with mental health conditions.

They must be able to:

c. explain the relationship between psychological and medical conditions and how psychological factors impact on risk and treatment outcome

Clinical research and scholarship

26 Newly qualified doctors must be able to apply scientific method and approaches to medical research and integrate these with a range of sources of information used to make decisions for care.

They must be able to:

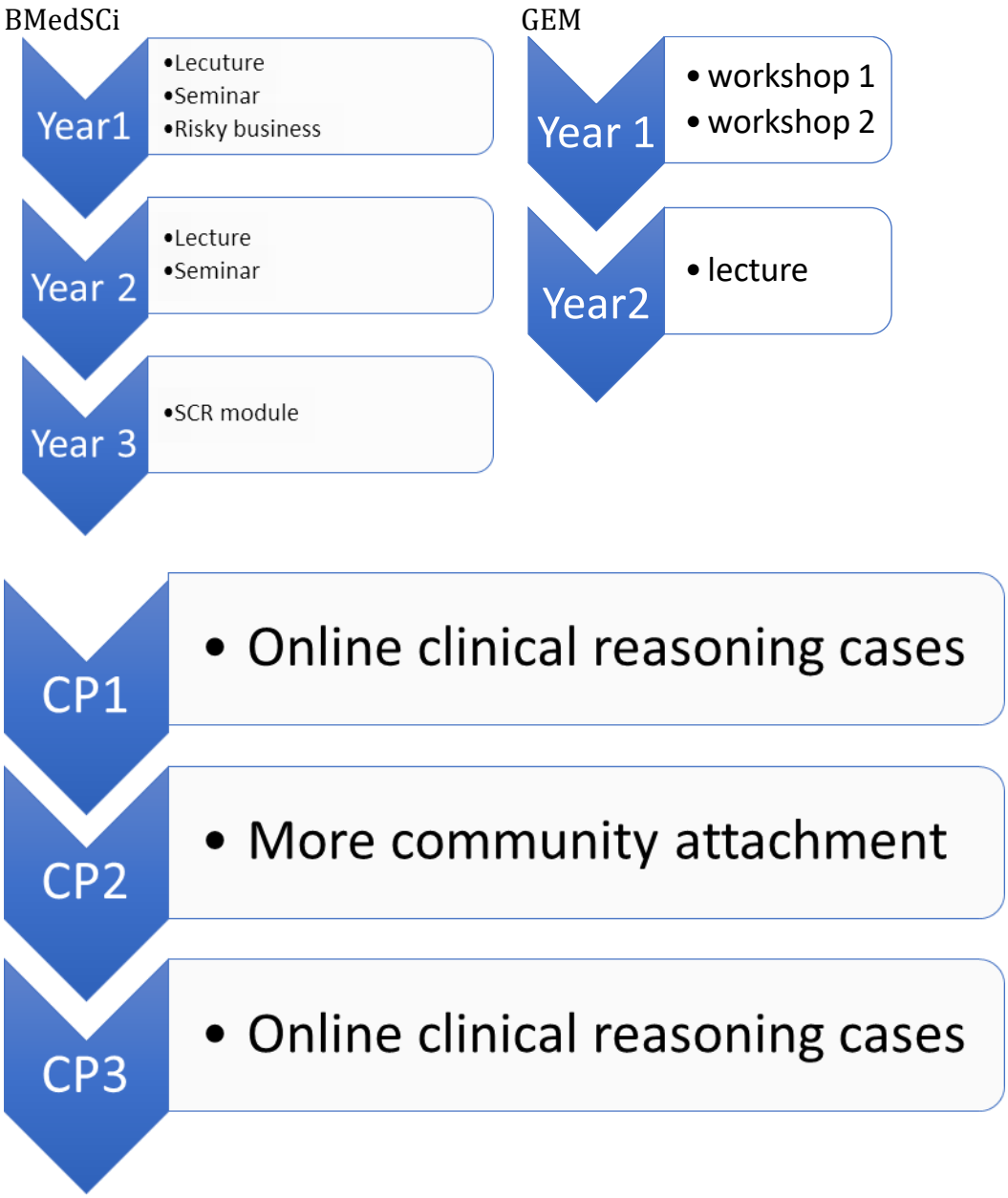
a explain the role and hierarchy of evidence in clinical practice and decision making with patients

b. interpret and communicate research evidence in a meaningful way for patients to support them in making informed decisions about treatment and management

i. describe the concept of personalised medicine to deliver care tailored to the needs of individual patients

j use evidence from large scale public health reviews and other sources of public health data to inform decisions about the care of individual patients

Appendix 4. University of Nottingham Core Curriculum



Here is the CR curriculum document for the students.

Table 7.2. The CR strand across the UG curriculum

Course Structure

BMedSci

Overall CR teaching

This new revised curriculum as a whole is intended to integrate and make learning clinically relevant. Case studies would be used throughout the week to inform teaching and would be rounded off by a case study workshop at the end of the week to engage the students in deep learning. It is not a PBL programme but it is case focused. The new curriculum is still based on a systems based integrated approach.

BMedSci Year 1

Core CR Teaching

One Introductory Lecture

One Seminar at Early Clinical & Professional Development Course (ECPD)

Optional Module: Risky Business

Lecture

The students receive an introductory lecture on CR. It includes the reasons why students learn basic sciences, how to put the basic medical sciences into a clinical context and how to make conceptual links between topics covered in different modules. This will provide a clinically oriented habit of mind, reduce personal errors in cognition and engage students in deep learning.

Seminar

During the ECPD course, the students have already had hospital visits, introductory lecture on clinical history taking and also a seminar on Cardiovascular and Respiratory history taking. On those sessions, the aim is to practice taking clinical histories and not necessarily to reach a diagnosis. During the seminar with record keeping, we will advice the students how to be an active listener. Why is this important? Osler's maxim said, "Listen to your patient, he is telling you the diagnosis". The way to become a better listener is to practice "active listening". This is where you make a conscious effort to hear not only the words that another person is saying but, more importantly, try to understand the complete message being sent. The stages of the development of listening skills in history taking are discussed. The pitfall in hearing and how to gather the information from various sources are considered. Finally, some stories about missing diagnosis because of listening errors are shared.

Optional module: Risky Business: Understanding and preventing Medical error

Part of this module, "factors influencing your Decision Making as a Doctor" is presented to understand the thinking process in the head of the decision maker, to appreciate the limitations we have as humans in perceiving and processing information that may be critically important, to know the contextually- and environmentally-bound phenomenon of decision making and CR, to consider the role of the patient and others in shared decision making and to appreciate the

TEAM; people around us can unlock the error in every step.

BMedSci Year 2

Core CR Teaching

One Lecture

One Seminar at Early Clinical & Professional Development Course (ECPD)

Lecture

In this lecture, the aim is to share the vocabulary of elements of CR, key models of CR, tips on how to develop CR skills and to know one's favoured biases.

There are two main models of reasoning, a fast, pattern recognizing, intuitive way of thinking (type 1); and a slow, controlled but high effort way of thinking. Dual process theory describes how the human brain has two distinct 'minds' when it comes to decision-making.

We could not live our lives permanently in a deliberate, slow, effortful way. In the same way, a lot of our clinician decision-making is intuitive rather than analytical. Despite the power of non-analytic reasoning, it has its own limitations so that analytic cognitive strategies have the potential to complement non-analytic thinking.

The most effective techniques in developing CR will be discussed.

Seminar

During the ECPD course, another CR workshop will be delivered. The aim of this interactive seminar is to discuss how doctors do hypothetic deductive reasoning to get to the diagnosis by using cue cards. CR in medicine usually starts with a presenting complaint.

The students will be asked to write the cue cards for differential diagnoses of patient's symptom using all available sources: textbooks, online resources or any previous lectures. Then, for each Diagnosis**,** Pathophysiology, Characteristics of typical presenting symptoms, Physical findings, Investigations +/- Management plan must be explored and discussed. (Compare-and-contrast assignments)

The students will appreciate the history generates the most hypotheses and the clinicians ask specific questions during the history in order to explore the hypotheses further. This exercise will enable the students to see the bigger picture of why they use the Calgary Cambridge framework, SOCRATES, take past medical history, personal history, family history, how the clinical examination makes the list of differentials smaller depending on the presence and absence of some findings, and how test results will narrow things down even more. This exercise will guide the students how to think about this process for the other symptoms.

BMedSci Year 3

Scientific Basis of CR (SCR Module) is delivered to all year 3 students who joined Life Sciences Homebase Modules. The purpose of this module is to facilitate experiential learning and CR. It is Patient centred course and the aim is that all participate in the problem solving.

GEM

Overall CR teaching

Problem-based learning (PBL) sessions

Core CR Teaching

CR is explicitly taught in the following:

- CR workshops
- Clinical skills 'exploring symptoms' workshops
- Evidence-based medicine lectures

9.

CP1-CP3

Overall CR teaching

. In clinical years, the students' clinical attachment will be varied. The development of your CR also depends on where you based and what learning opportunities you get. In order to get the consistency between all different sites, training the teachers "How to Teach CR in work place" is started. We make sure all the clinical teachers from different sites have new competencies to teach these skills.

The tips for you are:

- Improve your knowledge
- Practice to formulate differentials
- Practice history taking and physical examination
- Do problem lists
- Use precise medical terms in the problem list,
- Present it and get feedback
- Reflection on any knowledge gaps you have identified in the course of this clerking, and do strategic reading
- See as many patients as possible with common presenting symptoms and keep your own logbook

11.

Core CR Teaching

A graded series of case scenarios based on core clinical presentations will be provided on-line each month as CR Tests. These regular on-line clinical cases will be provided to develop thinking about CR.

The researcher has also proposed to introduce 'symptom-to-diagnosis approach teachings' in place of previous 'individual pathology and diseases approach teachings'.

ASSESSMENT

CR questions in summative assessment are specifically created that you cannot learn in the lecture but these could be learnt from the cases. Significant new changes are taking place within the exam across all 3 clinical phases and the knowledge paper is shifted from examining simple recall of knowledge to integration, interpretation and application of knowledge. OSCE stations will now increasingly move away from the traditional checklist marking to a hybrid domain marking scheme or domain based model. CR domain will be examined in almost every station. The duration and number of OSCE stations are changed and it is an opportunity to become more integrated and system based rather than uni-dimensional system based stations.

For the teachers

- ABC of CR is published (Cooper and Frain, 2016)
- Established clinical-reasoning.org website so that the students and the teachers could see the teaching materials (Cooper, 2015)
- Faculty training program will continue (SKH)