Uncertainty and Medical Education

A thesis submitted by

Dr Jonathan Sadler

MBChB, BSc (Hons), PGCert (Med Ed)

to Brighton and Sussex Medical School as a thesis for a degree of Doctor of Philosophy in Medical Education

June 2023

Volume I

Abstract

Understanding how to manage uncertainty in medicine is an essential part of clinical practice. Doctors and medical students alike suffer emotional anguish when they are uncertain. Despite this, there has been little inclusion of recognised ways to manage uncertainty in medical school curricula. This is especially concerning for those practising in the United Kingdom, as being able to manage uncertainty is a recognised requirement by the General Medical Council. How to teach medical students to manage this phenomenon thus warrants further study.

In a review of the literature, eight published interventions were found where teaching healthcare learners about uncertainty was the focus. How doctors and students actually learned to manage their uncertainty was, however, still unclear. Through interviewing 11 medical educators and 11 medical students in semi-structured interviews and focus groups, this thesis provides further insights into how to manage uncertainty. The medical educators described uncertainty in aleatoric terms, where possible outcomes were known but predicting which one would happen caused the uncertainty, and felt teaching should reflect this. However, medical educators felt that they themselves had learned about uncertainty over time and through non-specific clinical experiences rather than through direct teaching methods. The medical students described uncertainty in epistemic terms, where possible outcomes were unknown and infinite. They felt they had learned to manage this through interactions with near-peers and an acceptance that uncertainty was normal.

Analysing this data has revealed that students and doctors largely experience different forms of uncertainty. This implies that teaching needs to be intentionally tailored to the relevant audience based on their degree of clinical exposure. This thesis presents a proposal for managing uncertainty and lays the ground for future work that could test this proposal.

Table of Contents

Abstract 1
Table of Contents 2
List of Tables 5
List of Figures 7
Abbreviations 8
Preface 9
Acknowledgements 11

Declaration 12

1 - Introduction 13
1.1 Medical education in the United Kingdom and at BSMS 13
1.2 Designing appropriate research questions 15
1.3 Why focus on uncertainty? 16
1.3.1 Uncertainty and threshold concepts 19
1.4 The sources and types of uncertainty 20
1.5 Re-evaluating my research questions 23
1.6 Concluding thoughts 24

2 - Literature review 25
2.1 Introduction to the review 25
2.1.1 Objectives 26
2.2 Methods 26
2.2.1 Quality assessment 28
2.2.2 Data synthesis 29
2.3 Results and findings 29
2.3.1 Literature search 29
2.3.2 The literature 30
2.4 Synthesis of findings 37
2.4.1 Analytical themes 37
2.5 Discussion 41
2.6 Conclusions from the review 44
2.7 Concluding thoughts 44

3 - Methodology and Methods 46
3.1 My philosophical perspective and selecting an aligned methodology 46
3.1.1 The history and uses of phenomenography 51
3.1.2 First and second-order perspectives 52
3.1.3 The Anatomy of Experience 53
3.1.4 Phenomenography and Phenomenology: strengths and weaknesses 54

3.2 Methods 58
3.2.1 Data sampling and collection 59
3.2.1.1 Creating interview schedules 63
3.2.1.2 Collection and transcription 65
3.2.2 Data analysis 65
3.2.2.1 Unit of description: conceptions and categories 67
3.2.2.2 The outcome space 68
3.2.2.3 Validity and reliability 68
3.3 Ethical considerations 70
3.4 Outcomes of the research and concluding thoughts 71

4 - Findings and discussion - Medical Educators 73
4.1 Sampling and demographics 73
4.2 Findings 76
4.2.1 How did educators conceptualise uncertainty? 76
4.2.2 How did the educators feel they learned to manage their uncertainty and how do they currently manage the uncertainty they face? 80
4.2.3 Uncertainty in medical education 91
4.2.3.1 When do students experience uncertainty? 92
4.2.3.2 Should uncertainty be taught to students? 96
4.2.3.3 Have you ever tried to teach the concept of uncertainty to medical students? 99
4.2.3.4 Where does uncertainty in medicine fit in a medical undergraduate programme? 102
4.2.3.5 How would you teach medical students about uncertainty? 106
4.3 Discussion 111
4.3.1 How did educators conceptualise uncertainty? 111
4.3.2 How did the educators feel they learned to tolerate the uncertainty they faced or how do they currently manage uncertainty? 116
4.3.3 When do students experience uncertainty? 120
4.3.4 Should uncertainty be taught to students? 123
4.3.5 Have you ever tried to teach the concept of uncertainty to medical students? 125
4.3.6 Where does uncertainty in medicine fit in a medical school? 126
4.3.7 How would you teach medical students about uncertainty? 129
4.4 Summary and recommendations 133
4.5 Concluding thoughts 135

5 - Findings and discussion - Medical Students 137
5.1 Sampling and demographics 137
5.2 Findings 138
5.2.1 How did the medical students conceptualise uncertainty? 138
5.2.2 When do you experience uncertainty during training? 142
5.2.3 When do doctors experience uncertainty and how do they manage this? 145

5.2.4 How did medical students learn to manage uncertainty? 151
5.2.5 Should uncertainty be taught and how? 154
5.3 Discussion 160
5.3.1 How did the students conceptualise uncertainty and when did they experience uncertainty during their training? 160
5.3.2 When do doctors experience uncertainty and how do they manage this? 165
5.3.3 How did medical students learn to manage their uncertainty? 166
5.3.4 Should uncertainty be taught to medical students and how? 168
5.4 Summary and recommendations 172
5.4 Concluding thoughts 174

6. Synthesis 175
6.1 Answering the research questions 175
6.2 Research insights 178
6.3 Conceptual frameworks 178
6.4 A methodology for developing uncertainty management skills 181
6.5 Connections to the existing literature 184
6.6 Validity and trustworthiness 186

7 - Conclusions 189
7.1 Summary 189
7.2 Limitations and strengths 191
7.2.1 Literature review 191
7.2.2 Interviews with the educators 192
7.2.3 Focus groups with the medical students 193
7.2.4 Methodology 194
7.3 Areas for future research 194
7.4 Reflexivity and reflection 196
7.4.1 Reflexivity 196
7.4.2 Personal reflection 197
7.5 Conclusions 200

References 201

List of Tables

Table	Title	Page
2.1	Search Strategy	27
2.2	Summary of studies from a literature review about interventions to teach medical learners about uncertainty	35-38
3.1	The differences between phenomenography and phenomenology	58
3.2	Measures taken to improve rigour in phenomenographic analysis	69
4.1	Institutions	74
4.2	Pseudonymised participant information - medical educators	74-75
4.3	Outcome space for the conceptualisation of uncertainty in medical educators	79
4.4	Category - Self	83-84
4.5	Category - Other	87
4.6	Category - Time and Experience	89
4.7	Category - Unclear	91
4.8	Outcome space related to when medical educators feel that students experience uncertainty	94
4.9	Outcome space relating to if students should be taught about uncertainty	98
4.10	Examples of different methods used to teach students about uncertainty	101
4.11	Outcome space relating to different ways uncertainty has been taught	102
4.12	Outcome space relating to where uncertainty fits in medical school	105
4.13	Outcome space relating to ways of teaching uncertainty	108-109
5.1	Details for the focus groups	138
5.2	Outcome space for the conceptualisation of uncertainty by students	141
5.3	Outcome space for when students experience uncertainty	144

5.4	Outcome space derived from data concerning when medical students believe doctors experience uncertainty	147
5.5	Outcome space derived from data concerning how students believe doctors manage uncertainty	150
5.6	Outcome space relating to students learning about uncertainty	153
5.7	Outcome space relating to if uncertainty should be taught?	155
5.8	Outcome space relating to how uncertainty could be taught about and where it fits in the medical school curriculum	158-169
6.1	Outcome space for research	177
6.2	Validity measures for phenomenographic research with the respective evidence	187-188

List of Figures

Figure	Title	Page
2.1	PRISMA flow chart of the literature selection process	30
2.2	Thematic synthesis of descriptive and analytical themes identified in the literature of interventions used to teach medical learners about uncertainty	39
2.3	The placement in time of the eight interventions during the medical learning journey	43
3.1	The object of study in phenomenography	50
3.2	The anatomy of experience	54
4.1	Diagrammatic outcome space demonstrating how educators felt they learned to or currently manage uncertainty	90
4.2	Diagrammatic outcome space relating to when students are thought to experience uncertainty	96
4.3	Outcome space related to considerations needed when creating an intervention concerning uncertainty	110
4.4	Kolb's learning spiral	117
4.5	Maslow's hierarchy of needs	119
5.1	Venn diagram of medical educators' perceived times of when medical students experience uncertainty and actual times medical students are uncertain	164
6.1	A conceptual framework of the threshold of medical uncertainty	179
6.2	A diagram showing the differences between the teaching of and the learning about uncertainty	180
6.3	A conceptual framework of what the phenomenon of uncertainty means to medical education and how it could be learned, from the perspectives of medical students and educators	181

`

Abbreviations

A and E	Accident and Emergency	NIHR	National Institute for Health Research
BSc	Bachelor of Science	OSCE	Objective structured clinical examination
BSMS	Brighton and Sussex Medical School	PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for scoping reviews
CINAHL	Cumulative Index to Nursing and Allied Health Literature	SBA	Single Best Answer
COVID-19	Coronavirus disease 2019	SI	System International
CPQ	Clinical Prioritisation Questions	TAMSAD	Tolerance of Ambiguity in Medical Students and Doctors
CReME	Clinical Reasoning in Medical Education group	UK	United Kingdom
DK	David Kirtchuck	US	United States
DS	Duncan Shrewsbury		
ERIC	Education Resource Information Center		
FGD	Focus Group Discussions		
GMC	General Medical Council		
iBSc	Intercalated Bachelor of Science		
LbC	Learning-by-Concordance		
MDT	Multidisciplinary team		
MLA	Medical Licensing Assessment		
MMAT	Mixed Methods Appraisal Tool		
MSC	Medical Schools Council		

Preface

The journey taken by a person shapes their outlook and goals. Knowing my story will help the reader understand my motivation for undertaking this study.

I grew up in London where my parents were computer scientists. My medical career started at the University of Bristol from where I graduated in 2011 with a medical degree and an intercalated Bachelor of Science (iBSc) in virology and cancer biology. I moved to Oxford to start my life as a junior doctor and progressed through the early stages of anaesthetics training.

Although anaesthetic trainees are routinely placed on the intensive care rota, the worlds of anaesthetics and intensive care are diametrically opposite. Anaesthetics involved reacting in such a way as to arrive at an achievable and satisfactory outcome. Intensive care had a much less rigid job description. Every day I encountered patients who could not be treated elsewhere in the hospital. Whether there was a difficult diagnosis or a patient who was not responding to treatment or one who had simply taken the interest of that day's on-call intensive care consultant, they all were my problems. These patients became sources of uncertainty and anxiety, and ultimately distractions from the work I enjoyed.

This was not the only stress that I experienced during my clinical years. Every new rotation was a source of anxiety. I vividly remember starting a job in an accident and emergency (A and E) department where my anxiety manifested physically. Every patient and each interaction made me nervous. The uncertainty about how people would react caused me to tense my abdominal muscles. After three weeks I started to notice a bitter taste in the back of my throat - acid reflux. I eventually relaxed into the job, I knew a suitable answer for every problem, or at least knew where I could look to find one. I knew of ways of responding that would buy time without losing

face with either the patient or my co-workers. At the end of the rotation, the head of the department even asked me why I was not pursuing a career in Emergency Medicine, and I left with the feeling I had grown as a doctor and a person. I experienced similar episodes of anxiety and the accompanying acid reflux in subsequent posts, but never as severely as when I worked in A and E. Thinking back, uncertainty caused the problem.

In 2016 I moved from Oxford to Brighton and undertook a fellowship at the Royal College of Anaesthetists. I was assigned to a project exploring how Anaesthetics, Intensive Care and Pain Medicine fit into the medical student undergraduate curriculum (A. Smith et al. 2018; A. F. Smith, Sadler, and Carey 2018; A. Smith et al. 2019; Sadler et al. 2017). It was an opportunity to see how curricula were designed, and I found this more satisfying than my clinical work. I was proud to put my name on a significant study and I found working with academics highly stimulating. I was offered a second (teaching) fellowship at Brighton and Sussex Medical School where I could develop a Student Selected Component (in environmental medicine) and study for a Postgraduate Certificate in Medical Education. Subsequently, I was given this opportunity to pursue this doctorate and, naturally, I chose a subject I could relate to, a subject that caused me such discomfort: uncertainty.

Notably, this research was performed during a period of unprecedented uncertainty - the Coronavirus (COVID-19) pandemic.

Acknowledgements

This work has one name on the title page but that does not tell the whole story.

I would like to start by thanking Professor Juliet Wright who believed in me enough to encourage me to start this journey.

I would also like to thank the research group who guided me throughout the whole process: Professor Harm van Marwijk, Dr Clare Forder and especially Dr Duncan Shrewsbury. Without their constant support, I am unsure what this research would resemble.

To all the participants who gave up much of their time, thoughts and experiences. This work could not exist without them or the energy they gave me.

To the greater team at Southpoint, there would have been little joy in this work without the contribution of the department, as well as the regular tea and sympathy.

Finally, I would like to dedicate this work to my family. My parents have always taken an interest in my academic endeavours and have always made me feel that education is a worthwhile pursuit. My wife who has been supportive and encouraging throughout this whole period and who makes my life better on a daily basis. To my daughter Mackenzie, who was born in the same month that I started this research and proves that some uncertainty is enjoyable.

Declaration

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree, and does not incorporate any material already submitted for a degree.

Signed

Dated

1 - Introduction

1.1 Medical education in the United Kingdom and at BSMS

According to the Medical Schools Council (MSC), the representative body for medical schools, the United Kingdom has around 45 medical schools with a few more currently being created (Medical Schools Council 2022). The UK medical degree programme runs for between four and seven years and is a combination of undergraduate, postgraduate and hybrid models[1]. Course models differ depending on the medical school, with some universities offering largely didactic teaching and others offering problem-based learning style courses.

Students experience their first clinical placement at different stages depending on their institution. Some places restrict this exposure to the end of their third year of training, whilst others have a more graduated approach with increasing levels of clinical exposure until by the third year the majority of the student's time is spent in clinical areas.

Following successful completion of their medical course, students are ranked and placed into a foundation programme to start their careers as junior doctors. The levels of supervision in foundational roles vary greatly, with some roles being closely supervised and supernumerary and others being isolated. The learning curve is steep for all roles and the level of responsibility will be dramatically greater than for most newly qualified graduates.

Brighton and Sussex Medical School (BSMS) operates a five-year undergraduate medical degree program with an optional sixth year to study for an intercalated degree. The course is largely a taught course for the first two years with frequent

[1] Variations include: postgraduates on undergraduate courses, foundation to medicine years for students who do not have appropriate entry qualifications, shortened placements for postgraduates, intercalated years etc.

clinical immersion weeks, followed by three years of clinical placements. Students undertake regular summative assessments and complete their final examinations at the end of the first term in their final year.

In the United Kingdom (UK), the regulatory board for medical schools is the General Medical Council (GMC). The GMC determines what professional skills, knowledge and behaviours are expected from newly qualified doctors and thus what medical schools must teach. In their latest medical curriculum guide 'Outcomes for Graduates 2018', the GMC outlines the need for doctors to be able to manage uncertain problems or uncertainty eight times (General Medical Council 2018). The GMC describes *dealing with uncertainty* as a professional behaviour expected from all doctors. Three key points stand out from the document:

> [Doctors must] manage the personal and emotional challenges of coping with work and workload, uncertainty and change. - (GMC 2018, 10)

> [Doctors must] manage the uncertainty of diagnosis and treatment success or failure and communicate this openly and sensitively with patients, their relatives, carers or other advocates. - (GMC 2018, 12)

> [Doctors must] 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. - (GMC 2018, 17)

The medical licensing assessment (MLA), a new standardised exam that all UK medical students will likely have to pass before graduating, also contains guidance concerning uncertainty. The document lists managing uncertainty as an overarching outcome (Medical Licensing Assessment 2022). Explicitly:

> The ability to cope with uncertainty over diagnosis, prognosis, response to therapeutic interventions; medical science; and when to call for help. - (Medical Licensing Assessment 2022, 3)

And

> Deals appropriately with complexity and uncertainty including managing multimorbidity and prioritising tasks - (Medical Licensing Assessment 2022, 8)

There is little guidance given by the GMC about *how* doctors will arrive at these expected competencies. By completing this research, I aim to assist curriculum developers address what is expected from them by the GMC, so that future junior doctors will be better prepared to manage the uncertainty they may face when they start clinical work.

1.2 Designing appropriate research questions

Before starting the PhD, I spent a long time with my supervisors trying to develop appropriate questions. I was informally told by other students in my department that it was unlikely that I would be able to ask the most appropriate questions on my first attempt, due to my inexperience of research methodologies, but some broad questions would be useful to guide more relevant ones later. My initial review allowed me to sketch out some possible questions. The areas that I felt needed more research were: defining uncertainty and trying to find answers to how to teach students about uncertainty. This led me on a larger onto-epistemological journey and ultimately to admit that I was trying to answer questions before fully understanding what I was asking. Below are my initial questions (in section 1.5 are the questions I ended up researching).

How can medical students be prepared for uncertainty?

1. What is meant by uncertainty and how is it taught in medicine?

a. Is there a way of measuring uncertainty to demonstrate learning?

2. Does the literature reflect actual experiences of uncertainty?
    a. What are current junior doctors' experiences of uncertainty?
    b. What can be learned from their experiences that can be used to better prepare future doctors?
3. What recommendations or interventions would support the teaching of uncertainty to medical students?

I pondered these questions for many months, while I went back to work in intensive care for the Coronavirus disease 2019 (COVID-19) outbreak in 2020. First, before performing any research, I tried to familiarise myself with the field of work so as not to repeat it. I reviewed the literature surrounding the teaching of uncertainty (Chapter 2) to understand what research had occurred, and to see if my questions would be valid or useful. During the review, I became aware that I might not be able to *solve* this complex area but I should be able to progress the knowledge, shrinking the knowledge gap, and that this would be a suitable overarching goal (Fraser and Greenhalgh 2001).

1.3 Why focus on uncertainty?

Apart from the concerns of the GMC and my own curiosity, there are other reasons to focus on uncertainty. There are recognised implications in medicine for those who feel unable to manage the uncertainty or ambiguity they face[2]. These include the impact on well-being and on career and speciality choice (Hancock and Mattick 2020; Geller, Faden, and Levine 1990; Gerrity, DeVellis, and Light 1992; Ilgen et al. 2019). Uncertainty in medicine has also been described as a threshold concept, which might make learning about uncertainty more complex, which I have discussed below (Meyer and Land 2003; Land 2016).

[2] Frequently referred to as an intolerance of uncertainty or ambiguity

Clinician well-being is an inherently important area of research. An inability to manage uncertainty or ambiguity has been linked with a number of more specific outcomes including burnout (draining one's emotional reserves), resilience (the ability to adapt) and psychological distress (Lemaire and Wallace 2017; Grote, Raouf, and Elton 2012). Research has found that those with a poorer ability to manage uncertainty consider themselves less resilient and more susceptible to burnout (McCulloch et al. 2005; Kimo Takayesu et al. 2014; Kuhn, Goldberg, and Compton 2009; Lally and Cantillon 2014; Simpkin et al. 2018). Doctors and medical students who were found not to recognise uncertainty in clinical practice ordered more tests on patients and were considered to be more judgmental of those they felt were undeserving (Wayne et al. 2011; Korenstein et al. 2022). In addition, researchers have found an association between uncertainty and affect, either positive (excitement) or negative (unpleasant emotions) (Anderson et al. 2019).

Other studies have linked the ability to manage uncertainty with career choice. Some of the literature suggested that students with an inability to manage uncertainty were more likely to follow careers in anaesthesia and surgery rather than psychiatry and general medicine, which are considered to have higher amounts of uncertainty (McCulloch et al. 2005; Merrill et al. 1994; Gerrity, DeVellis, and Light 1992). Others have made a link between career dissatisfaction and poor uncertainty tolerance (Kuhn, Goldberg, and Compton 2009; Kimo Takayesu et al. 2014).

Tolerance of uncertainty is considered by some to be an important objective measure associated when discussing medical uncertainty (Hillen et al. 2017). Much work has been done in this area along with the associated tolerance to ambiguity, including the creation of scales that can measure said features (Hillen et al. 2017; Gerrity, DeVellis, and Earp 1990; Geller, Faden, and Levine 1990; Hancock et al. 2015; Kuhn, Goldberg, and Compton 2009; Schor, Pilpel, and Benbassat 2000). The earliest scale of note was developed by Budner et al. in 1962 and aimed to measure an intolerance to ambiguity, not necessarily in medicine (Budner 1962). This scale has been regularly updated and re-tested for validity and is a foundation for many current scales (Sobal 1992). Geller et al. published papers in the 1990s, attempting

to better orient the questions towards those in medical fields (Geller, Faden, and Levine 1990; Geller et al. 1993). Other important measurement tools in use include Gerrity's Intolerance of Uncertainty scale and Freeston's Intolerance of Uncertainty scale (Gerrity, DeVellis, and Earp 1990; Freeston et al. 1994). Notably, Freeston himself has stated that the scale was not designed to measure a change in tolerance to uncertainty, or intolerance to uncertainty as he describes it, and therefore should not be used in the evaluation of any teaching (Freeston 2022). These scales were evaluated by Hancock et al. for the development of the Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD) scale in 2015 (Hancock et al. 2016). Following its creation, the research group tested the scale demonstrating validity (Hancock et al. 2017; Hammond et al. 2017; Hancock et al. 2016).

Hancock et al. and Hillien et al. have also given consideration to the question of whether uncertainty/ambiguity tolerance is in fact a trait (an inherent permanent characteristic) or a state (that varies depending on the person's psychological context) (Hancock et al. 2015; Hillen et al. 2017). If it is the latter, then measuring uncertainty tolerance at an inopportune time in a medical student's career has less utility. It may be constructive to consider how to help students to *manage* their uncertainty rather than measure how they *tolerate* it.

A 2017 review of tolerance towards ambiguity or uncertainty scales by Hillen et al. discovered a total of 18 different scales had been created (Hillen et al. 2017). This demonstrated that perhaps there was no perfect way to measure tolerance to uncertainty or that the universally accepted way has yet to be developed. These findings are to be expected as even defining uncertainty was challenging (see 1.4), therefore difficulties or lack of clarity in measurement would surely follow. Once tolerance to uncertainty is calculated, I am still unsure how variable this number is for each individual, and I am unaware of any literature that has reviewed interpersonal scores[3]. There are also bigger implications such as once a number has

[3] For example: If the same person takes the assessment on different days, how different will their results be?

been calculated, what does that mean? I am reminded of a line from the ever-quotable Hitchhiker's Guide to the Galaxy:

> We demand rigidly defined areas of doubt and uncertainty! — Douglas Adams (1981)

I am unsure of the merits of further measuring tolerance to uncertainty for my research, which has already been done by others (Reis-Dennis, Gerrity, and Geller 2021). There have also been recent studies that suggest that some measurement scales are not reliable when used on medical students (Stephens, Nazmul Karim, et al. 2022). Instead, in relation to preparing students for clinical careers, my focus will be on a greater *understanding* of the phenomenon of uncertainty and on methods of *managing* it.

1.3.1 Uncertainty and threshold concepts

From my experience and according to the research of others, teaching students how to manage uncertainty has been missed from most curricula (Luther and Crandall 2011; Simpkin and Schwartzstein 2016a). This might be due to the fact that uncertainty in medicine is a threshold concept, a challenging, troublesome and transformative concept that is misremembered by those who have transitioned through the threshold[4] (Meyer and Land 2003). I am suggesting that those who develop curricula might not remember what it was to suffer from uncertainty. Reading more broadly, many have identified uncertainty in medicine as being a threshold concept (Randall et al. 2018; Gaunt and Loffman 2018; Bhat et al. 2018; Collett, Neve, and Steven 2017; Stopford 2021; H. Jones and Hammond 2022). Due to the nature of threshold concepts, this labelling has implications for those trying to understand uncertainty as well as those trying to teach it.

[4] Other features of threshold concepts include them being: irreversible, integrative, bounded, having a degree of liminality, reconstitutive and discursive (H. Jones and Hammond 2022).

1.4 The sources and types of uncertainty

An early stage of this research was addressing the difficulties when defining uncertainty. I was not alone in finding that uncertainty is a challenging concept to define[5] (Simpkin and Armstrong 2019). An attempt to analyse and clarify what was meant by uncertainty tolerance concluded that:

> Although uncertainty tolerance is critical in healthcare and other domains of life, we have demonstrated that its meaning has remained unclear and its measurement has varied substantially…the basic question remains: What is the essence, or fundamental nature of uncertainty tolerance? - (Hillen et al. 2017, 74)

A more recent systematic review relating to *diagnostic* uncertainty also concluded that:

> The term diagnostic uncertainty lacks a clear definition - (Bhise et al. 2018, 103)

It appeared that the academic literature was in agreement that there is a lack of consensus about how uncertainty was defined. Both reviews suggested lengthy placeholder definitions for uncertainty. As the research undertaken for this doctorate concerns uncertainty in general and not specifically diagnostic or tolerance of uncertainty, I have decided not to incorporate these definitions in the research and instead accept that there is variation in both meaning and understanding of the term.

The narrative review by Hillen et al. described many of the other features associated with uncertainty, including identifying the types of uncertainty (Hillen et al. 2017). These were comprehensively described by Han et al. in 2011, building on earlier

[5] Currently there is no literature review of the term uncertainty per se, I have therefore included related terms (diagnostic uncertainty and uncertainty tolerance).

work, as being caused by *ambiguity*, *complexity* or *probability* (Han, Klein, and Arora 2011; Mishel 1983; Babrow, Kasch, and Ford 1998). These three elements can be seen as factors or *causes* of uncertainty that are relevant in healthcare settings, and help to delineate uncertainty in the medical field. The example below further illustrates the three different *causes* of uncertainty:

Ambiguity is a vagueness or plurality of meaning for words including a variation in interpretation (Kim and Lee 2018). For example: “My parents and sibling are coming to visit me today. They don’t eat fish.” This seems like a fairly straightforward sentence until you understand that the speaker’s sibling is gender-neutral and uses the pronoun ‘they’. This use of the word ‘they’ means either that all three visitors do not eat fish or that only the sibling does not eat fish, and thus there is ambiguity leading to uncertainty about how to cater for the visitors. Throughout the literature, uncertainty and ambiguity have been used fairly interchangeably, although one can be considered a source of the other (Hancock et al. 2015). For this work, I have attempted to clarify when I specifically mean ambiguity.

Complexity is created from a variety of different components interacting with unpredictable results (Babrow, Kasch, and Ford 1998). For example: “My parents and sibling are coming to visit me today. I want them to have a good time so I am cooking my fish special.” This sentence includes much complexity. Prior information relating to the individuals would suggest that at least one member of the visiting party might not enjoy their meal. However, maybe some people will tolerate something that they do not enjoy to be polite and ensure that the host is not insulted. There is also uncertainty about what constitutes a ‘good time’ and if one negative element impacts a whole visit. Or maybe the speaker has accounted for the dietary needs of all the individuals. Either way, it is the complexity that is causing the uncertainty in the example sentence.

Probability is when multiple outcomes are possible (Smithson 1993). For example “My parents and sibling are coming to visit me today. I’m making fish but can cook some sausages as well in case someone is unwilling to try the hake. We also have

emergency pasta." In this example, there is uncertainty about the reaction of the sibling to the proposed meal, however, this has been accounted for to ensure that all needs are still met. Often percentages are associated with possible outcomes.

Han et al. expanded on the three types of uncertainties (ambiguity, complexity or probability) with what they labelled 'substantive' issues (sources of uncertainty) which add a medical context to the previous types described above (Han, Klein, and Arora 2011). They include scientific[6], personal[7] and practical[8] issues, which can all be caused by ambiguity, complexity or probability. Han also included a question of direction for the uncertainty or 'locus': Has the uncertainty been caused by the clinician or the patient?

Others have tried to establish alternative sources of uncertainty or simply tried to further develop the ones listed above. A number of different taxonomies of uncertainty have been created with differing levels of sophistication. Wray and Loo divided all uncertainty into informational or inherent in type (Wray and Loo 2015). This model separates uncertainty into what can and what cannot be known, with little appreciation for uncertainty relating to probability or the fact that these sometimes change. Others have classified sources of uncertainty into technical (e.g. inadequate data), personal (e.g. not knowing the patient's wishes) or conceptual (e.g. an inability to apply scientific understanding to the current situation) (Beresford 1991). This model is perhaps a bit too simplistic and again excludes probability-based uncertainty.

Many of the models of how uncertainty is contextualised had an overreliance on specific sources of uncertainty, which will continue to change or be added to as understanding progresses. The causes or types of uncertainty appear more universally applicable across the spectrum of medical practice. The most current models for defining types of uncertainty have been described by both Han and

[6] Such as diagnostic uncertainty, conflicting treatment recommendations or direction of causality

[7] Psychosocial and existential issues

[8] Uncertainties related to the practicality of giving care and the abilities of colleagues

Simpkin and Armstrong (Han 2021; Simpkin and Armstrong 2019). They distinguish between aleatoric (or stochastic) and epistemic uncertainty. Aleatoric (probabilistic) uncertainty describes uncertainty related to chance or random variability, for example: rolling a die and getting a specific number. All the possible outcomes are known but which one will occur is up to chance. Epistemic uncertainty relates to limitations in knowledge, which can either be due to the limitations in scientific understanding or the ability of the user to apply the knowledge to the situation.

For example, imagine if there was the spread of a novel virus. Initially, the symptoms and treatments relating to the virus would be epistemically uncertain, as not enough would be known about the virus. Clinicians managing patients would not know if signs and symptoms were related to the virus or other ongoing pathologies or generalised hysteria related to the media. After some research into the virus, the list of associated symptoms and suitable treatments would be known, likely due to a better understanding of the pathological processes of the virus. After some time the spectrum of symptoms exhibited when contracting the virus would be considered aleatoric, as different people would exhibit a different variety of a *known* collection of symptoms.

The model of uncertainty, being either aleatoric or epistemic, is the one that I have chosen to use for this research.

1.5 Re-evaluating my research questions

After I completed the initial part of the research, I had a better understanding of uncertainty, complications linked to uncertainty and the current scope of knowledge. This allowed me to reconsider and rewrite my initial questions to try and provide answers in areas that I felt were most needed:

1. What is meant by uncertainty and how is it currently taught in medicine?

2. What do medical educators and medical students think about uncertainty?

3. What do these findings mean for uncertainty in medical education?

1.6 Concluding thoughts

Uncertainty is a pervasive phenomenon that is relevant to medical practice and has many detailed facets that can be explored. There is an overall lack of consensus about how uncertainty is defined and measured, in general as well as in particular in the context of medical education and practice. Uncertainty is problematic, not simply due to its lack of unifying definitions but also due to the range of emotions felt and behaviours performed when uncertain and the impact this may have on learner and practitioner well-being. In the next chapter, I have investigated how uncertainty has been taught to medical students.

2 - Literature review

In this chapter, I have discussed the literature identifying published interventions for teaching students about clinical uncertainty that I discovered by performing a scoping review. I reviewed the eight relevant studies of varying quality. I synthesised the themes from the methods of teaching to distil four important themes that might be important when considering future ways to teach learners about uncertainty. I then discussed what this means and contemplated the relevance of tolerance towards uncertainty when discussing how students learn about uncertainty.

2.1 Introduction to the review

To answer my research questions and to become better acquainted with this field of research, I conducted a literature review. I decided that since the field of knowledge was still developing a scoping review would be the most suitable, although I did consider other review types (Munn et al. 2018). I discussed the format with my supervisory team as well as consulting the systematic review service PROSPERO and the National Institute for Health Research (NIHR) database for systematic reviews, both of whom confirmed that a scoping review would be the most suitable (PROSPERO 2022). Following the review, I performed a thematic synthesis of the interventions[9], as I felt that the specifics were less important than the themes uniting them (Barnett-Page and Thomas 2009).

[9] I consider an intervention to be any active method incorporated into a curriculum e.g. lectures, seminars, simulation, planned discussions, group work etc

2.1.1 Objectives

1) To find all published interventions that had been used to teach medical learners about uncertainty
2) To synthesise the themes between these interventions to help form guidance for future interventions

2.2 Methods

I conducted the review with assistance from Duncan Shrewsbury (DS) and David Kirtchuck (DK) (a member of the departmental research laboratory). I followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for scoping reviews (PRISMA-ScR) checklist (Tricco et al. 2018).

I made the decision to include all medical learners, rather than only medical students, as I considered uncertainty to be a problem that was not unique to qualified doctors and therefore any intervention was likely to be transferable between all medical areas. Since experts and novices learn in different ways and have vastly different amounts of clinical exposure[10], it is likely that these interventions would not be relevant to students. I therefore excluded papers about teaching healthcare specialists who were past the formative stages of their training, such as any who had completed their post-qualification training (Persky and Robinson 2017). Only published primary studies in the English language were considered. Non-primary studies (such as opinion or review pieces), protocols and papers about non-medical learners were excluded, as were studies where uncertainty was not the main focus of the intervention. The type of intervention was not an exclusion criterion, nor was the date or location it occurred at.

[10] Clinical exposure is essential when addressing uncertainty, as medical uncertainty is considered a threshold concept and therefore understood differently by those on either side of this threshold, assuming that most students are prior to the threshold and most doctors are through the threshold.

Before starting the review, I contacted local library services and asked them to help me develop a search strategy. On the 16th of July 2020, I searched the following databases using my search strategy (Table 2.1): Pubmed, Medline, Web of Science, Scopus, Education Resource Information Center (ERIC), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and PsycINFO. Relevant synonyms of uncertainty, intervention and medical learners were included in the search strategy (Table 2.1). As such, I considered the search term 'ambiguity' to be relevant as many consider ambiguity to be a cause of uncertainty and therefore this term might return valid results (see Section 1.4) (Han, Klein, and Arora 2011). Of note, following the pilot search, uncertainty and its synonyms were only included if they were part of the title or abstract of the study, as the word uncertainty was frequently used in a context that was not relevant to this review.

Table 2.1 - Search Strategy

Search term	**Field**
*Uncertain** or certain*or ambig* or reason*	Title or abstract only
and	
Student* or nurse* or physio* or occupation* or psycho*or resident* or intern* or foundat* or junior or doctor or undergrad* or GP or General*	All
and	
*Intervention** or teach* or education* or simulat* or learn* or experience* or reflect* or curricul* or train*	All

Following the searching of databases, I transferred and compiled the results on a password protected Google Sheet ("Google Sheets" 2022). I removed all duplicates and foreign-language papers. I then screened the papers by title and abstract, removing any papers that did not meet prior eligibility criteria. I read all remaining abstracts, with DK independently reading the abstracts to ensure correlation for inclusion. Any disagreement was discussed until resolution with further input from DS. Further papers were added after reviewing the references of key papers and after contacting other authors in the field.

All papers that met the inclusion criteria were read in full to ensure that they were relevant. This was repeated by DK. Cohen's kappa coefficient between the first two authors for all articles entering the final analysis was 1.0 (McHugh 2012). My data extraction started with simple demographic data and included: Study name, summary of the intervention, number of participants, type of learners and implications (Table 2.2).

2.2.1 Quality assessment

Prior to analysis, I selected an assessment tool to allow for the comparison of the quality of each paper. The Mixed Methods Appraisal Tool (MMAT) allowed for the appraisal of both the quality of the study as well as potential sources of bias (Pluye et al. 2009; Hong et al. 2018). The MMAT appeared to be an ideal tool as it facilitated the assessment of a broad range of study designs, which, based on a pilot literature search, was a likely outcome when assessing uncertainty-related interventions. The MMAT has different sections to use when appraising different study designs. I have included the salient points of this information in the summary table (Table 2.2). I used the findings of the MMAT assessment of each study, a global comparitive, as

well as my own experience as an academic peer reviewer, when considering how much value to place on each paper during the synthesis of the data.

2.2.2 Data synthesis

I extracted the methods section of each study for the purposes of thematic synthesis (Thomas and Harden 2008). The data relevant to my research questions was the descriptions of the interventions themselves, which were laid out in the methods section of the studies. Thematic synthesis was selected as the analytical approach as it is described as being able to "bring together and integrate the findings of multiple qualitative studies" (Thomas and Harden 2008, 2). Other methods of synthesis, such as critical interpretive synthesis, framework synthesis, textual narrative synthesis and others were considered at this stage, but I considered them not as able to synthesize the diverse methods (Dixon-Woods et al. 2006; Pope and Mays 2020; Lucas et al. 2007; Thomas and Harden 2008). NVivo 12 was the platform I chose to use to perform the synthesis (Jupp 2006).

2.3 Results and findings

2.3.1 Literature search

The database search yielded a total of 2776 papers, with an additional 63 through reviewing references and contacting authors (Figure 2.1). Following the removal of duplicates, non-English foreign language papers and unobtainable papers there remained 1561 papers. These were screened by title and abstract, with all ambiguous abstracts being placed for a full review. Following title and abstract screening, 156 papers were reviewed in full. Eight papers contained relevant interventions and were then assessed for quality using the MMAT before the synthesis of their methods was conducted. Data were extracted as described (Table 2.2).

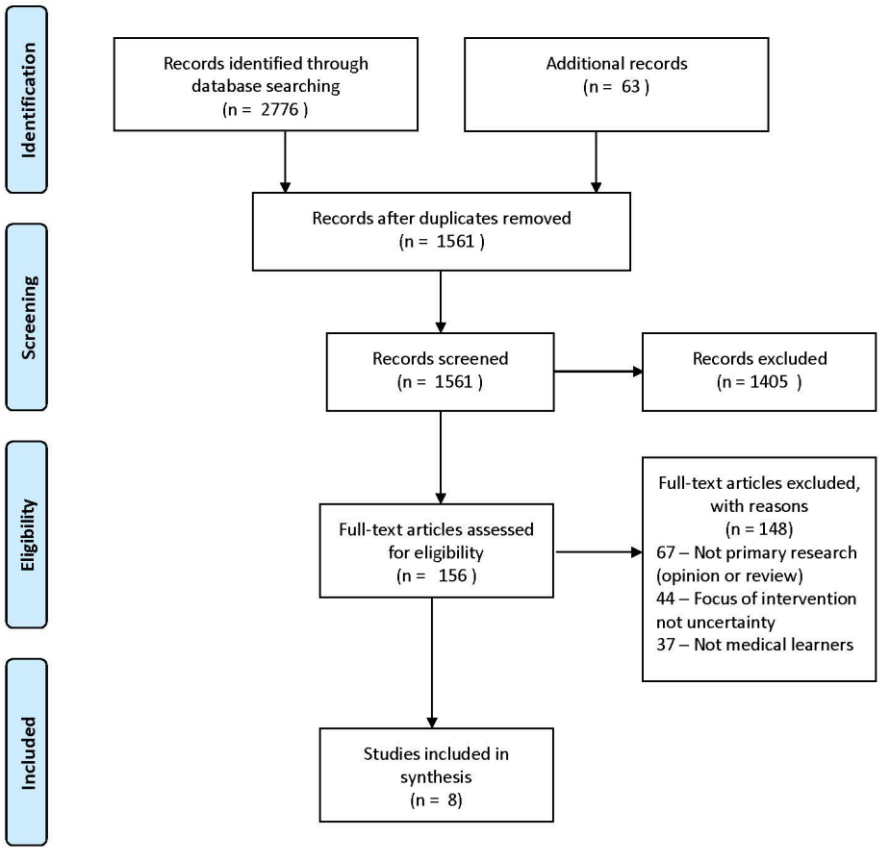


Figure 2.1 - PRISMA flow chart of the literature selection process (Tricco et al. 2018)

2.3.2 The literature

The eight papers that I found during the review approached uncertainty and how to teach students about it very differently. Below I have summarised each of the studies, how the paper describes uncertainty and the intervention itself. Following a description of each study I have given a personal appraisal of the paper, which I wrote after completing its quality assessment. Of note, most papers made no mention of bias or did nothing to account for any confounding variables associated with letting self-selecting groups of students participate, and had very low response rates with unblinded analysis of any results. I have presented the papers in alphabetical order of titles. Table 2.2 found below, contains the study name, a summary of the

intervention, sample size, type of learners, the implications of the study and then the main points from the MMAT.

Olsen et al. (2018) undertook a study of simulation with paediatric trainees in the United States (US) to explore uncertainty. All trainees on placement participated in one simulation, followed by a further related simulation six months later. The uncertainty arose from clinical diagnostic uncertainty about genetic disorders with the trainees expected to communicate this uncertainty to actor-patients. The communication skills of the trainees were assessed and were shown to improve by the second simulation. Overall, the intervention was enjoyed and seen as relevant by the trainees who partook, with a high response rate and noted objective change in communication skills. This intervention seemed a realistic, if stressful, way of learning how to communicate difficult diagnostic uncertainty to patients.

Sam and his team at Imperial developed a new form of written question-based assessment to allow for the inclusion of uncertainty in undergraduate assessment in their study (Sam et al. 2020). Students were given alternatives to Single Best Answer (SBA) type examinations where they had to select a single response (normally out of five possibilities) to a clinical question. Instead, they were given Clinical Prioritisation Questions (CPQ), which allowed for the ranking of responses based on clinical likelihood. This aimed to teach students that there was rarely a single answer to a clinical situation, which was a change to normal examination and was thought to be more clinically realistic. The students self-reported an improved tolerance towards uncertainty. This seemed to be an appropriate way to start bridging the gap between the early parts of the medical course, where answers are considered objectively correct or incorrect, and the later parts of the course where students are expected to have sophisticated clinical reasoning skills.

Golden et al. (2018) performed an evaluation of simulation-based teaching of communication of bad news and uncertainty in the specific overlap of the fields of obstetrics and neonatology. Students attended the same simulation twice, once on

their neonatal attachment and then on their obstetric attachment[11]. The focus of the simulation was the communication of diagnostic uncertainty in obstetric patients and how this was managed in a team setting. 401 Students experienced the intervention and the evaluation was through a bespoke self-assessment questionnaire about confidence. Overall, the study suggested that the students felt more confident with uncertainty following the simulations. This study allowed students to experience and manage realistic clinical uncertainty and also provided them with multiple opportunities to practise communicating this, in a method that incorporated complexity and other challenging elements of medical practice.

Liou et al. (2019) suggested a novel approach to introducing uncertainty to medical students involving 'equine-facilitated learning'. The study took 38 self-selecting students from years one and four to a horse stable where they were introduced to horses and asked to diagnose the horse. The uncertainty was due to the alien nature of the horse-as-patient and the lack of verbal communication. The study utilised Budner's Tolerance of Ambiguity Scale to objectively measure a change in tolerance and suggested that students in year one became slightly more tolerant and year four students remained at the same tolerance level following the intervention, which is an alarming finding. I felt that this was a resource-intensive intervention design, largely due to the novelty of the approach, to accomplish a simplistic learning outcome: uncertainty is always present.

Learning-by-Concordance (LbC) by Fernandez et al. (2016) studied several related interventions approximately consisting of a clinical scenario where students were asked to give an answer and rate how confident they were about this answer. Students were then shown how experts would answer the questions, often with multiple responses and then provided with links to other resources. Three cohorts from different year groups at a university totalling 653 students took part in the study. The uncertainty arose from both the students considering how to respond to the scenario and from the experts describing the complexity themselves. The

[11] Or vice versa

method itself appears to be a valid way of demonstrating how different experts would manage uncertainty. The intervention was perhaps too complex as sometimes students did not feel ready for the amount of information and reasoning[12].

Scott et al. incorporated uncertainty in the form of a single simulation during a simulation day for final-year students, in their study (Scott et al. 2020). Students volunteered for a simulation where many of the findings were vague and there was no obvious clinical situation occurring. The uncertainty arose from diagnostic uncertainty and general ambiguity in all findings and being unsure who to call for non-specific advice. This improved on the realism of normal simulations where there is typically a very obvious diagnosis. Analysing the debrief following the simulations, the students found the simulations both relevant and challenging. I felt that this was a very appropriate and safe way to introduce students to experiencing clinical uncertainty, and would be easy to replicate.

Bentwich and Gilbey used art and discussion to introduce the 120 first-year students to uncertainty (Bentwich and Gilbey 2017). The intervention consisted of a lecture to the cohort observing a piece of art[13] and then a follow-up discussion about multiple interpretations. Empathy towards suffering was also discussed. I felt that the uncertainty of multiple meanings or differing interpretations in art in this intervention was too far from clinically relevant uncertainty. My thoughts are supported by the feedback from the students in the paper, which suggests that the intended message was lost, although they only received feedback from 67 students. I also felt that the results collected were being overrepresented in the discussion and that the reference quotes could easily have been interpreted differently to how the authors chose to understand them. Perhaps the overall novelty and attempting to convey too many humanitarian principles in one single intervention clouded any potentially valid learning outcomes.

[12] Some students just wanted to know the correct answer and described frustration in never finding this

[13] Normally depicting something medically related

Gaulin and Cao created a surgical learning aid to reduce the uncertainty during surgery (Gaulin and Cao 2005). The study consisted of 20 medical students on their surgical attachment, being randomly assigned to having a surgical learning aid (instructions on how to perform the virtual surgery) present or absent while using a surgical trainer (a virtual laparoscopy set). The authors found that those with the surgical aid completed the task faster. The uncertainty arose from the students not knowing the order in which to perform the tasks and was reduced by the aid itself. To me, this was a very simplistic derivation of medical uncertainty, with a resulting intervention that was unlikely to be generalisable to other clinical contexts.

Table 2.2 - Summary of studies from a literature review about interventions to teach medical learners about uncertainty

Study Name	Summary	Sample	Type of learners	Implications	Appraisal
Case-based simulation empowering paediatric residents to communicate about diagnostic uncertainty (Olson et al. 2018)	Serial uncertainty simulations communicating diagnostic uncertainty to actors were conducted with self-reflection and group discussions	19	Graduate paediatric residents	Practising difficult communication improves management, especially when communicating about uncertainty	MMAT 4 - Quantitative descriptive No clear research question. Sampling population representative of the population. Measurement using Kalamazoo Essential Elements Communication Checklist – Adapted (KEECC-A). High response rate and appropriate analysis.
Clinical prioritisation questions: A novel assessment tool to encourage tolerance of uncertainty? (Sam et al. 2020)	Students as individuals, then as a group answered prioritisation questions, an alternative to single best answers	245	Undergraduate clinical	Allowing the ranking of answers gives space for reasoning and accepts that there is uncertainty. This is also more clinically realistic than single best answers	MMAT 4 - Quantitative descriptive Research question clear (assessment of new format). Sampling representative of the population. Statistical assessment appropriate. Response rate high (234/245)
Development and Evaluation of a Simulation-Based, Medical Student Teaching Session for Communicating Bad News and Uncertainty Along the Obstetric-Neonatal Continuum (Golden et al. 2018)	Team-based simulation, to break uncertain news in an obstetric and neonatal setting	401	Undergraduate clinical	Allowing students to practise talking about uncertainty while breaking bad news, allows them to appreciate the nuance around this difficult communication. Practising working as a team helps to manage situations when uncertain	MMAT 4 - Quantitative descriptive Sample representative and strategy relevant. Student satisfaction was measured through surveys and free-space questions. High response rate therefore non-responder bias chances were lower.
Foreign bodies: Is it feasible to develop tolerance for ambiguity among medical students through Equine-Facilitated learning? (Liou et al. 2019)	Students were asked to observe then attempt to train a horse	38	Undergraduate clinical and pre-clinical	What the uncertainty intervention is, is not necessarily relevant, as learning to tolerate uncertainty is not unique to clinical medicine	MMAT 4 - Quantitative descriptive Research question clear. Low sample rate and unlikely that the sample was representative of the population (as self-selecting). Measurement of pre and post-intervention using validated Tolerance of Ambiguity scale. Low response rate (61%) Authors note that some findings were not

					statistically different, therefore unclear how effective intervention was at increasing tolerance towards ambiguity.
Learning-by-Concordance (LbC): introducing undergraduate students to the complexity and uncertainty of clinical practice (Fernandez et al. 2016)	Students shown worked case examples with differing expert answers, for self-assessment or in a classroom setting. Three different year groups.	653	Undergraduate pre-clinical and clinical	Giving multiple answers from experts, with reasoning, both improves students' understanding and displays the inherent uncertainty of medicine.	MMAT 1 - Qualitative Qualitative descriptive study. Thematic analysis was performed on a single free text box. Likely a single question would be inadequate. Findings derived from data. Coherence between data shown and results.
Medical education, simulation and uncertainty (Scott et al. 2020)	An uncertain simulation added to a days simulation training	12	Undergraduate clinical	Involving uncertainty in simulation improves familiarity of how to respond without a diagnosis	MMAT 1 - Qualitative Clear research question. A qualitative approach was appropriate. Rigour has been applied to the process. The findings appear to represent the data as there is coherence between the data, analysis and interpretation.
More than visual literacy: art and the enhancement of tolerance for ambiguity and empathy (Bentwich and Gilbey 2017)	A lecture looking at art, then a discussion about if this helped understand that there is more than one meaning	120	Undergraduate pre-clinical	Art can help teach about multiple solutions to a problem	MMAT 4 - Quantitative descriptive Low return of results therefore unclear if the sample represents the population. The chance of non-response bias is high. Unclear effect of intervention as no baseline observations. Discussion not supported by results.
Surgical learning aid: Reducing uncertainty for the novice during simulated minimally invasive surgery (Gaulin and Cao 2005)	Students randomised to having a surgical guidance sheet, to see if this helped improve surgical speed during a simulation	20	Undergraduate clinical	Having a learning aid present during testing allows learners to complete a practical task faster and reviewing this information was not perceived as a greater workload.	MMAT 2 - Quantitative randomised controlled trials. Unclear randomisation, unclear in groups similar at baseline, unclear if data complete, the unclear effect of the intervention. Assessors were not blinded. Unclear how valid perceived workload is as a variable. The authors note “original hypothesis was not fully supported by examining the dependent variables”.
Study Name	**Summary**	**Sample**	**Type of learners**	**Implications**	**Appraisal**

2.4 Synthesis of findings

Thematic synthesis was performed on the eight papers (Thomas and Harden 2008). The methods were read line by line and descriptive codes were generated independently by myself and a colleague (DK). These codes were discussed, compared, translated, organised into a hierarchy and converted into common descriptive themes, all with the assistance of a third reviewer (DS) who had not read the papers, allowing them to remain more objective when describing the reasoning behind each code. A final total of 79 codes was/ere generated and grouped into 13 descriptive themes. Consideration and analysis of these themes followed with the descriptive themes being placed into one or more of four analytical themes (Figure 2.2). Some themes that were apparent in a few of the papers detracted from the study and did not follow the trends from the current academic literature (discussed below).

2.4.1 Analytical themes

Acknowledging or confronting uncertainty

Facilitating students to identify and address their uncertainty was the first theme. The studies that involved simulation and debriefing enabled learners to experience and contemplate realistic uncertain dilemmas (Golden et al. 2018; Olson et al. 2018; Scott et al. 2020). This allowed students to practise how they would react in clinical situations and provided a space that would allow the student to better understand their own thought processes. The question-based studies incorporated uncertainty by making students justify their answers, or rank all possible answers in order of suitability (Bentwich and Gilbey 2017; Fernandez et al. 2016). This demonstrated, to the students, that there was a range of acceptable answers to most clinical situations and how important understanding and justification are.

Grounded in reality

Six of the interventions tried to recreate a realistic or recognisable medical environment or situation (Golden et al. 2018; Gaulin and Cao 2005; Fernandez et al. 2016; Sam et al. 2020; Olson et al. 2018; Scott et al. 2020). This was through either a case-based approach or simulation. The studies that were based on real-life settings had a clearer focus for the learners. Communicating bad news or uncertain results was also a theme that may have added more relevance to the intervention (Golden et al. 2018; Olson et al. 2018). What was lacking from the lower-quality interventions was this grounding in reality (Liou et al. 2019; Bentwich and Gilbey 2017). From the feedback in the studies, it was apparent that learners struggled to consistently translate the novel teaching into actionable clinical recommendations.

Professional skills

As uncertainty is a phenomenon that is experienced throughout medical training and beyond, it is understandable that many studies describe how it can be taught longitudinally[14] or as a professional skill[15] (Simpkin and Armstrong 2019; Fernandez et al. 2016; Liou et al. 2019; Golden et al. 2018). One intervention encouraged learners to write down when they had experienced uncertainty in a clinical setting and then had them discuss this as a group, exploring a range of possible responses (Olson et al. 2018). This suggests that the management of uncertainty cannot be 'taught' in a single lecture but needed to be both experienced and then discussed. Reflection and discussion in a safe environment, two techniques often used during professional skills teaching, were used as tools in the debrief section in two interventions (Olson et al. 2018; Scott et al. 2020).

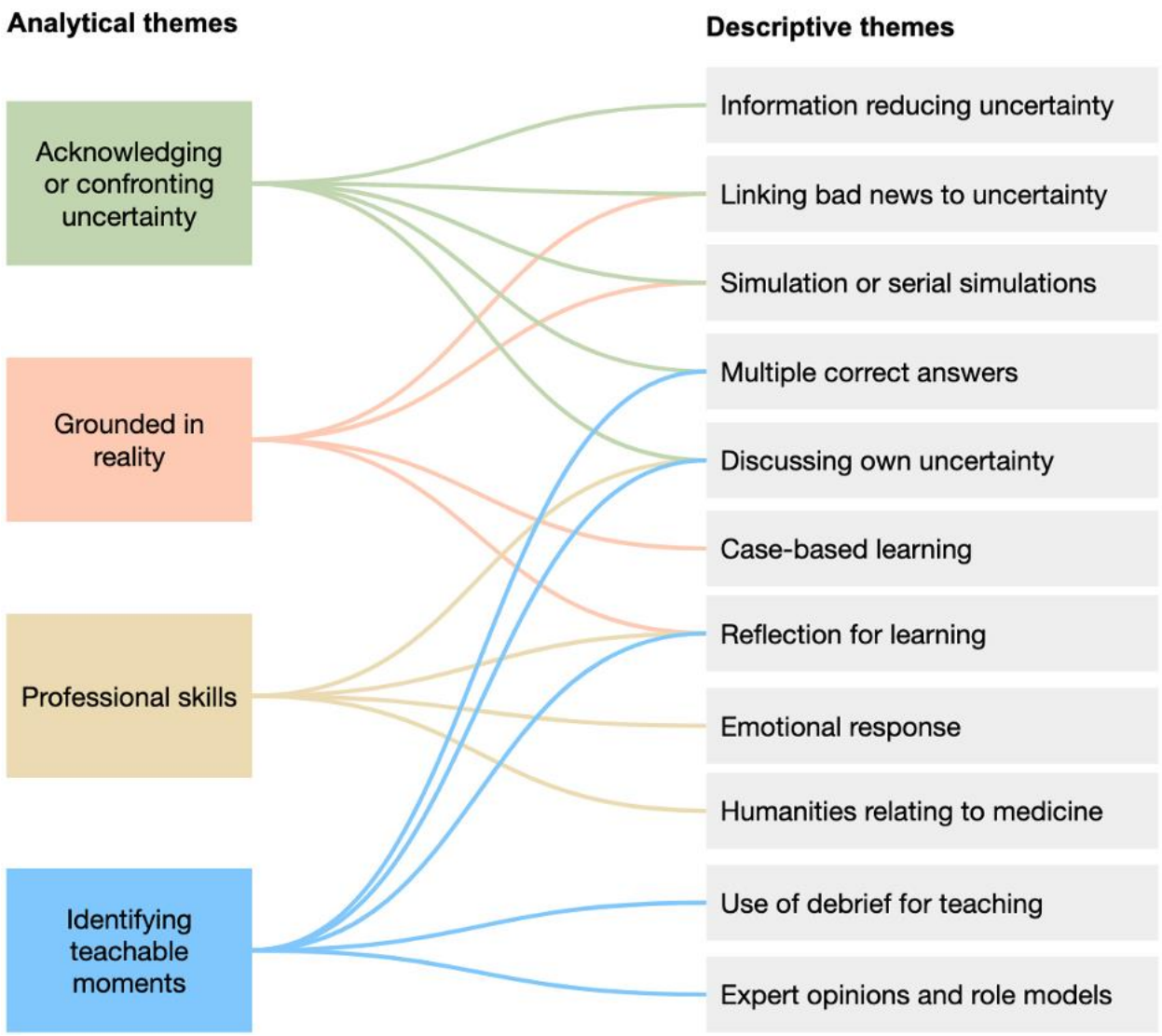
Identifying teachable moments

[14] A subject that is revisited many different times throughout training and beyond

[15] A collection of skills, not necessarily clinical, that are expected from all doctors (GMC 2018)

The ability to identify that uncertainty was the issue in common to a variety of different problems and was the final analytical theme that I identified. Using debrief, a tool encompassed by all the interventions that had some form of simulation, learners were guided to explore their uncertainty (Golden et al. 2018; Fernandez et al. 2016; Olson et al. 2018; Scott et al. 2020). Encouraging learners to identify uncertainty during reflection, perhaps through sharing their concerns and working through them as a group, allowed interventions to make the teaching of uncertainty more relevant and contextualised within clinical practice.

Figure 2.2 - Thematic synthesis of descriptive and analytical themes identified in the literature of interventions used to teach medical learners about uncertainty



Other Themes Identified

I identified two themes during the analysis that I considered irrelevant for future medical interventions in this area. The first theme was having multiple options equating to being uncertain. Two papers described providing multiple options as being the same as teaching students how to manage their uncertainty (Fernandez et al. 2016; Sam et al. 2020). While I recognise that this might be considered uncertainty by some, I felt it was an oversimplification of the phenomenon and may not be generalisable. Providing students with several options without allied explanations is unlikely to increase their ability to manage uncertainty, rendering the approaches that this theme alludes to as unhelpful or irrelevant to an evidence-informed pedagogical approach.

The second theme that I identified was the creation and analysis of a bespoke measuring tool, to measure the 'success' of the intervention. Almost every intervention (seven of the eight papers) used a novel tool. Considering how much progress has been made in the field of measuring tolerance of uncertainty and ambiguity (Section 1.3), I felt that a previously validated tool would have been more appropriate and would have allowed for more direct comparison[16]. Only one paper used a previously validated tool (Liou et al. 2019).

Summation of themes and recommendations for interventions

The four analytical themes helped illuminate what is required for future interventions:

1. The intervention would be more engaging if it is clinically realistic, where learners can instantly understand its importance and are not overwhelmed by the novelty of the situation and can make an easy link to their own clinical future.

[16] This study was done before the work of Stephens et. al which suggested that scales should be used with caution and had only internal validity (Stephens, Lazarus, et al. 2022; Stephens, Karim, et al. 2022).

2. Uncertainty should not be hidden or a secondary learning outcome. An element of the intervention should be about identifying and acknowledging problems caused by uncertainty, followed by a discussion on how they could best be managed.

3. Allow for any intervention to be repeated or have several related interventions, to encourage a greater appreciation and recognition of why the teaching is relevant, or have discussions about uncertainty on professional learning days.

2.5 Discussion

A number of key discussion points arose from the review and synthesis. Overall, I was surprised by the lack of published studies on what I consider to be one of the most crucial elements of medical learning: understanding how to manage our uncertainty. Perhaps the initial focus of the review, being solely on discrete interventions and not broader teaching, might have limited what could have been studied in the literature about learning how to manage uncertainty. I have detailed the remaining limitations of this review in the limitations part of chapter 7 (Section 7.2.1).

Search strategy

The search strategy was designed to uncover all relevant published interventions. Two out of the final eight papers included used the word 'ambiguity'. The majority of medical titles used the word ambiguity in the context of nursing roles or genital ambiguity, which is clearly a different field. 'Certainty' as a search term did not locate any results that were included in the final review. There is still much overlap between these terms, however, I would not recommend using the term certainty when performing similar searches.

Results, quality assessment, bias and synthesis

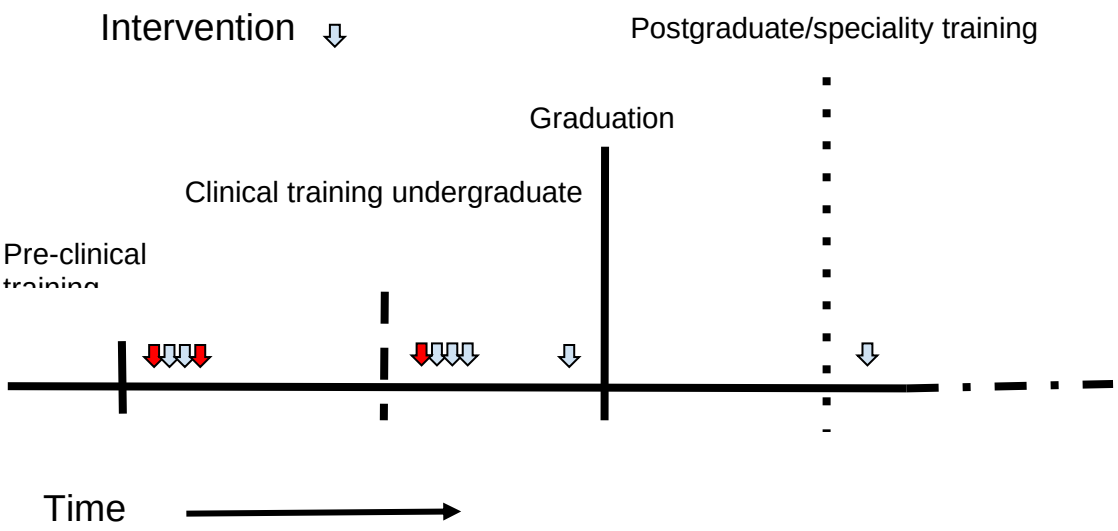
The strategy yielded eight different papers of greatly varying quality. As described earlier, a few papers started with what I considered to be an overly narrow premise, by oversimplifying uncertainty, reducing all uncertainty to being only aleatoric uncertainty. As uncertainty is challenging to define and has different meanings to individual people (Section 1.4), many forms of uncertainty were addressed depending on the intervention being used. As the field matures, it is likely that the nuances concerning which sort of uncertainty is important to experience or teach about will continue to develop. How to successfully manage uncertainty has yet to have a clearly defined threshold of competency, so assessing any intervention success would always have been problematic (Ilgen, Watsjold, and Regehr 2022). Most interventions aligned with the current emphasis in medical education on reflective learning (Sandars 2009; Kelly et al. 2022).

The MMAT was beneficial when assessing the quality of the papers and it helped me highlight areas which lacked academic rigour throughout the varying types of studies. The quality of self-analysis was lacking in some of the interventions and I doubt many of the results would be repeatable. I therefore considered the results with some caution. The stronger papers had more relatable applications and could likely be more easily incorporated into a medical curriculum.

Seven out of the eight papers had interventions aimed at undergraduates (Figure 2.3). This finding brings up other questions concerning where best any intervention should be placed. As highlighted by the learning by concordance paper, which used a similar intervention to three different year groups (1st, 2nd and 3rd), the more experienced learners saw the intervention as being more relevant to their practice (Fernandez et al. 2016). This suggests that teaching about the inherent nature of uncertainty in medicine might not be seen as relevant to those without sufficient experience. Academics have described uncertainty as difficult for students to learn about early in the course because they do not know the boundaries of knowledge expected of them (Gheihman, Johnson, and Simpkin 2020). Alternatively, learners

might change their learning preferences throughout their studies. One intervention delivered to first-year medical students used horses as surrogates for uncertainty. Hypothetically, this intervention might be more appropriate if it was directed towards the paediatric residents, further along with their training, who might be able to better abstract the learning from the novelty. Future work is therefore required to find out where or when in a medical learner's journey any intervention would have the greatest impact.

Figure 2.3 - The placement in time of the eight interventions during the medical learning journey (one intervention was repeated three times and is highlighted in red)



Many of the interventions discussed how to teach students how to *tolerate* the inherent uncertainty of medicine. This implies that uncertainty is an entirely negative phenomenon, which learners must learn to tolerate, and that the students are not active in their experience of uncertainty. The focus is on the uncertainty rather than the student. An alternative term to tolerate, and one I feel is more appropriate is *manage*. This change in vernacular re-centres the student as being active in their learning and comprehension of uncertainty and also allows for more positive connotations of uncertainty.

2.6 Conclusions from the review

Understanding how to teach the management of uncertainty is a rapidly developing area. Given the considerable amount of published literature concerning the phenomenon of medical uncertainty, I found surprisingly few published interventions directed towards teaching its management. As uncertainty is so dynamic and complex, interventions should perhaps be aimed at laying the foundations of how to manage this or normalisation of the phenomenon rather than expecting learners to be masters of uncertainty. This review was successful in synthesising the themes that have been used when trying to teach the management of uncertainty. Papers which presented realistic and relatable situations, where uncertainty could be discussed with peers or experts, or even allowed for direct confrontation of uncertainty, were considered the appropriate guiding themes for future interventions and seen more favourably by the students in the studies. I also felt that if a measurement tool was required, then a previously validated one would be more useful than a bespoke one (see section 1.3 for examples). The interventions that were not grounded in clinical medicine still needed more development before they can be truly considered to appropriately teach the management of uncertainty. The placement in the medical curriculum of any intervention, and what constitutes acceptable management also needs further research.

2.7 Concluding thoughts

This literature review greatly helped me to understand both the field and how people believe uncertainty could be taught. It also allowed me to have a better understanding of how some education designers thought about uncertainty, as well as what was felt to 'work' and 'not work'. The themes created from the synthesis of the review are useful to keep in mind when answering the research questions. The review also helped with how I conceptualised uncertainty, moving from tolerating the phenomenon to trying to work out how people learn to manage it. In the next

chapter, I have described my philosophical perspectives and detailed the methodology and methods for undertaking my research.

3 - Methodology and Methods

In this chapter, I have described my own philosophical beliefs and how this led me to adopt a particular methodology. I then detail the tenets of the methodology, phenomenography, in particular the history of phenomenography and how it has been implemented, comparisons with phenomenology and why I think it is the most suited methodology for my research. I have then described and justified the methods I used for the remaining research, semi-structured interviews for those in medical education and focus group discussions for medical students. I have also described the creation of the materials that I needed to perform these methods and the phenomenographic analytical process, as well as the measures I used to ensure that my findings were valid and reliable.

3.1 My philosophical perspective and selecting an aligned methodology

To be able to describe how I selected a research methodology, I first considered my ontological (theory of being) and epistemological (theory of knowing) perspectives (Ferrier 1856, 46). I was, like most doctors, educated from a realist or positivist perspective, where all things could be measured or calculated if you knew the right equation (Bunniss and Kelly 2010). This was true at school, medical school and then again for the majority of my medical postgraduate life. This was understandable, as many in medicine describe it as following 'the scientific method' where theories are formed and then measured to form proof (Sturdy 2007). All physical phenomena can be measured to some degree, and every measurement can be expressed in terms of System International (SI) base units (second, kilogram, kelvin, ampere, metre, mole and candela) or derived as products of powers of the base units. (Lehmann and Conn 1979). From this perspective, reality is cold, objective, universal and independent of

human thoughts and beliefs (Jenkins 2010). I was taught almost exclusively through realism at the expense of understanding any other views of reality.

I understood realism. Objectivity and quantification simplify understanding. To pick an example from anaesthetics, I have described the actions of propofol, an anaesthetic drug. I do not need to know how propofol works, but if I inject 5 mg/kg of propofol into a person's bloodstream, they will be in a coma until it wears off. I did this every day to many different patients. I can use a formula to describe the actions of propofol without knowing exactly how it works. The truth about which neurological receptors are blocked by propofol to cause the coma in the patient may never be fully understood and will always be a simplification of the actual process. Focusing on the calculation required to describe the actions of propofol allowed me to dispense propofol without ever truly understanding its mechanism of action. There are other phenomena of interest that cannot easily be measured and hence are not amenable to formulaic calculation. In these cases I believe that it is inappropriate to apply a realist philosophy.

Relativism accepts that all truth is relative and the nature of reality can only be known from an individual's perspective (O'Grady 2002). This is a concept that I do not fully agree with. I believe that an individual's truth can be objectively wrong even to them. For example, I am red-green colour blind[17]. I accepted that my vision, and my truth, are incorrect compared to how the rest of the world sees colour. I willingly accepted that my truth is not generally accepted, but that there is an opposed and generally accepted truth. I also note that understanding how others see colour is highly contested as is whether colour is an objective property at all (Byrne and Hilbert 2003).

I believe that objective reality and subjective reality are interlinked and, for any individual, the relationship between them changes with growing knowledge and experience. This is relevant for my research concerning uncertainty. According to the

[17] Compared with an average human, I have fewer red sensing cones.

literature, for some, uncertainty was a concept that can be objectively measured and compared (Hancock et al. 2017). For others, uncertainty was entirely subjective and unique to them (Land 2016). For this research, I have therefore rejected Realism and Relativism, in favour of an ontological stance somewhere in between: Non-dualism (Neges 2013). The results I arrived at will be considered objective by some and subjective by others.

Epistemology is the branch of philosophy that describes the theory of knowing (Seel 2011). I am of the opinion that knowledge and understanding are due to beliefs, motivations and reasoning. These will be different for every individual. Understanding the beliefs, motivations and reasoning of individuals in context allows for an understanding of their knowledge. Therefore, my philosophical paradigm can be seen as that of an interpretivist (Schwandt 2000).

My philosophy and opinions about truth and knowledge have determined the methodology I felt was most relevant in answering the research questions[18]. These questions were about increasing the understanding of the phenomenon of uncertainty in the context of medical education. Understanding rather than quantifying requires a qualitative approach. My philosophical assumptions indicate that there can not be a definitive universal answer to any of the questions. Instead, I have uncovered a range of possible answers that will allow readers to better understand the depth and intricacies of the phenomenon as well as the critical elements required when teaching about it. Considering this, the most appropriate way to answer these types of questions was to ask people about their understanding of this phenomenon.

There are a variety of different methodologies aligned with my philosophical paradigms that could have been used to arrive at answers to the research questions

1. [18]What is meant by uncertainty and how is it currently taught in medicine?
2. What do medical educators and medical students think about uncertainty?
3. What do these findings mean for uncertainty in medical education?

including: phenomenography, action research, design thinking, phenomenology and grounded theory (brief description of the methodologies in Appendix A).

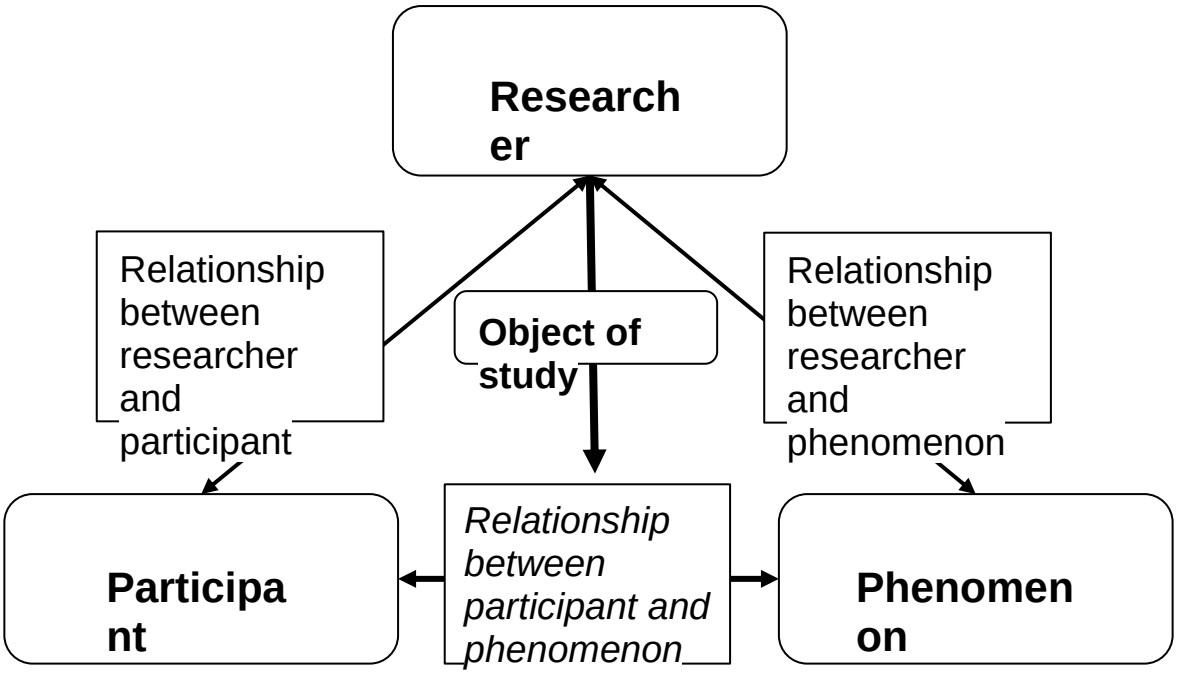
I selected phenomenography as the principal methodology for this research. To understand why I used this methodology, and how it aligned with my philosophical perspective, I have described the ontological and epistemological foundations of the methodology.

Phenomenography is a methodology that is not aligned with either realism or relativism, instead accepting a non-dualistic perspective (Åkerlind 2005; Hajar 2021). Marton explains this further:

> "There are not two worlds: a real, object world, on the one hand, and a subjective world of mental representations, on the other. There is only one world, a really existing world, which is experienced and understood in different ways by human beings. It is simultaneously objective and subjective." (Marton 2000, 102)

Phenomenography is said to assume an interpretivist epistemological stance, allowing for, and indeed accepting many different interpretations of reality and knowledge rather than a single universal truth (Han and Ellis 2019; Stenfors-Hayes, Hult, and Dahlgren 2013; Brown and Dueñas 2020). Interpretivism even allows for the inclusion of a number of different interpretations of reality even within a single person (Pitt 2014).

In phenomenography, understanding is said to be derived by the researcher from studying the relationship between participants and a phenomenon in question (Figure 3.1).



.

Figure 3.1 - The object of study in phenomenography adapted from Khan (2014)

Before deciding on this methodology, I read widely and sought counsel from those more familiar with qualitative work. I explored multiple different methodologies. My key consideration when reading about different methodologies was: is this methodology suitable for answering my research questions? Before accepting that phenomenography was suitable and aligned with my personal philosophy, I discussed the plan with the research team followed by experts outside of the research team (Professor Kathleen Galvin) and then eventually well-known scholars in the phenomenographic discipline (Professor Terese Stenfors-Hayes). The conversations confirmed that my interpretation of the methodology was an appropriate way to arrive at the aims of the research. Following this, Dr Clare Forder, a local academic familiar with phenomenography was invited onto the research team.

This chapter will further outline why I believe phenomenography is the most appropriate methodology, make comparisons with phenomenology, and explore some of the tenets of the methodology including second-order perspectives and the anatomy of experience. Of note, phenomenography has also been cited as a suitable

research methodology for doctoral studies, being sophisticated enough that it arrives at valid conclusions to complex problems, but simple enough that it can be done in a timely manner by individual students (Åkerlind 2005). I have also detailed the methods and data analysis below (Section 3.2).

3.1.1 The history and uses of phenomenography

Phenomenography was conceived by a group of researchers in Gothenburg studying approaches to learning during the mid-1970s (Dahlgren 1976). The word phenomenography had originally been penned earlier in 1954 in works by Sonnerman when critiquing a phenomenological technique as used by Jasper, remarking that Jasper's use of phenomenology would be better termed phenomenography (Sonneman 1954). Phenomenography and phenomenology are often conflated and this earlier coining of the term was merely coincidental and should not be confused with how it is being used for this research. The etymological difference in suffixes, '-ology' and '-ography', refer to a study of a subject and a description of a subject respectively ("Etymonline - Online Etymology Dictionary" 2022). With this understanding, one of the key differences between the two can be described. Phenomenology aims to directly explore a phenomenon while phenomenography aims to explore how participants perceive this phenomenon (Figure 3.1). I explore this in further depth below (Section 3.1.4).

Since its conception in the late 1970s, phenomenography has been used to answer questions about teaching and learning, typically in higher education settings (Marton 1981; Åkerlind 2008; Daniel, Mann, and Mazzolini 2016; Tight 2016). Steadily gaining in popularity, by the early 2000s phenomenography had been used to research the teaching of mathematics, engineering, computer science, management as well as medical and nursing education and healthcare research, amongst others (Gordon and Nicholas 2015; Jennifer, Case, and Light 2011; Yates, Partridge, and Bruce 2012; Stenfors-Hayes, Hult, and Dahlgren 2013; Teeter and Sandberg 2017).

Phenomenography has also been used to map out more philosophical phenomena and concepts such as happiness (Moyano-Díaz 2016).

Phenomenography uses purposive sampling, which is a selective sampling technique that targets participants to provide relevant data or offer variation (Akerlind, Bowden, and Green 2005; Etikan, Musa, and Alkassim 2016). Expressions of how a person experiences, understands, perceives or indeed conceptualises a phenomenon, and how this differs from others, is one of the main aims of a study (Seel 2011). Results tend to be in the form of a number of qualitatively different ways a phenomenon can be experienced. These different ways can be logically connected and are displayed in what is known as the outcome space (Section 3.2.2.2). As any one particular way a phenomenon is experienced or understood might be more meaningful than others, critical elements to learning about a phenomenon might be discerned and understanding these has the potential to alter how the phenomenon can be learned or taught about (Runesson 2005). Therefore detailing and describing the variation of understanding might have implications for how a phenomenon is taught in the future or alter the current pedagogical design.

There are currently no substantial guidelines on how to include uncertainty in a medical curriculum despite this being a GMC requirement (Section 1.1). Using a phenomenographic approach, I have assembled the critical elements concerning how uncertainty can be incorporated into a curriculum or teaching that would be applicable to institutions or individuals (Section 6.4).

3.1.2 First and second-order perspectives

A first-order perspective is said to be one of a person describing their experiences of the world (Marton 1981). A second-order perspective is said to be that of a person describing their thoughts about their experiences of the world. In other words:

> "Content of thinking rather than the process of thought." (Marton 1986, 32).

It is important to both define these perspectives and recognise their differences, as one of the tenets of phenomenography is the focus on second-order perspectives (Yates, Partridge, and Bruce 2012). Yates described this as a difference between *how* versus *what* or *why?* In her description of the concept, she uses an example of searching the internet, with a first-order perspective being concerned with *why* somebody would use the internet to search for something, whilst a second-order perspective is concerned with *how* people experience this. For phenomenographers, the first order is the medium of data inception and the second order is the variation and the interest of the researcher (Åkerlind 2018). This means certain questions or phrasing of questions are more suited to the phenomenographic methodology. For example: 'How do medical students learn to take medical histories' or 'What are the different ways that medical students learn to take medical histories?' would be better suited than 'Why do students learn to take medical histories?'. Whatever answers are given, all described experiences are treated as valid (Yates, Partridge, and Bruce 2012).

3.1.3 The Anatomy of Experience

Another component of the phenomenographic philosophy concerns both how experiences are consciously observed and how sources of variation are considered. Marton, Booth and Pong describe that experiences have both a referential aspect (what this experience means) as well as a structural aspect (how to differentiate a specific experience) (Figure 3.2) (Marton and Booth 2013; Marton and Pong 2005). The structural aspect can be further conceptualised as having an internal and external horizon. The internal horizon identifies how an experience relates to different aspects of itself (how one part of an experience may be different to a later part of the same experience) and as a whole, while the external horizon regards how the experience is different from the background. These aspects are said to be both intertwined and co-exist for all experiences and a researcher must be consciously aware of these aspects to fully comprehend a phenomenon (Han and Ellis 2019).

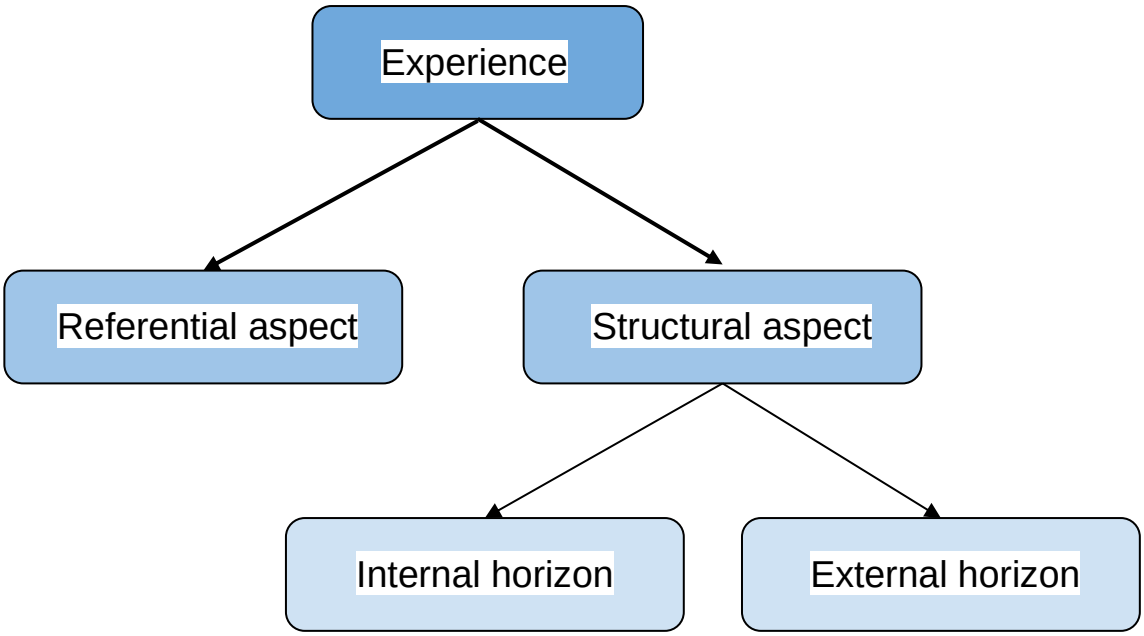


Figure 3.2 - The anatomy of experience - Adapted from Marton and Booth (2013, 88)

For example, for an uncertain experience, the referential aspect is recognition of uncertainty and what this means. For the structural aspect, the external horizon surrounds the experience with more certain ones whilst the internal horizon identifies different uncertainties within the experience itself.

3.1.4 Phenomenography and Phenomenology: strengths and weaknesses

Phenomenography is an empirically derived (from experimentation rather than philosophy) research methodology, originally used to research the variation of experience of a phenomenon in higher education (Marton 1981). Phenomenography has frequently been compared with phenomenology and that will be reviewed in this section along with other strengths and weaknesses of the methodology.

Despite their close etymology, phenomenography is not related to phenomenology (Marton 1981). There is much literature by phenomenographic researchers

explaining how the methodology was not derived from phenomenology and instead was created empirically (Hasselgren and Beach 1997; Cibangu and Hepworth 2016; Marton 1981). Marton, one of the originators of the methodology attempted to remove any ambiguity in 1981 by outright stating:

> "Phenomenography is not an offspring of phenomenology." - (Marton 1981, 40).

Both phenomenography and phenomenology research the experience of a phenomenon with the former focusing on collective experience, whilst the latter is normally focused on that of the individual (Cossham 2017). Phenomenography is used to explore how groups vary in their understanding of a phenomenon in comparison to an exploration of the phenomenon itself. My research was about how groups (medical educators and medical students) conceive and understand uncertainty, with a focus on the people trying to teach and learn about it, rather than an exploration of uncertainty as a concept.

Uncertainty as a concept has such a varied meaning to individuals that focusing on a few individuals might lead to findings that would not be broad enough to fulfil the research aims of providing valid recommendations to those wishing to incorporate uncertainty into their curriculum. A phenomenographic approach actively seeks variation and values all contributions equally (Walsh 2000). If I had used a phenomenological approach, the polarising views of a few individuals, who might be more forthcoming in expressing their opinions, could have dramatically altered the research findings. Many direct comparisons between the two methodologies have been made (Table 3.1) (Cibangu and Hepworth 2016; Stolz 2020; Hasselgren and Beach 1997). One study applied methodologies to the same data (Larsson and Holmström 2007). The conclusions of the study were that phenomenography was preferred for educational settings.

Table 3.1 - The differences between phenomenography and phenomenology adapted table from Barnard, McCosker and Gerber (1999, 214)

Phenomenography	**Phenomenology**
A second-order perspective in which experience remains at the descriptive level of participants' understanding and research is presented in a distinctive, empirical manner	A first-order perspective
The aim is to describe variation in understanding from a perspective that views ways of experiencing phenomena as closed but not finite	The aim is to clarify experiential foundations in the form of a singular essence
An emphasis on collective meaning	An emphasis on individual experience
The analysis leads to the identification of conceptions which are used to form categories. Logical connections between categories are displayed in an 'outcome space' (See Section 3.2.2.2)	Analysis leads to the identification of meaning units. These are used to generate themes
Phenomenography	**Phenomenology**

Moving away from a comparison with phenomenology, there are other recognised strengths and weaknesses of the methodology. Phenomenography has traditionally been used to explore deep learning of complex phenomena in higher education (Bussey, Orgill, and Crippen 2013). As understanding uncertainty in medicine has been identified as a threshold concept, a complex phenomenon in itself, phenomenography seems ideal for researching how students learn about any threshold concept (Stopford 2021; Collett, Neve, and Steven 2017; Meyer and Land 2003; Randall et al. 2018; Bhat et al. 2018; Gaunt and Loffman 2018).

Phenomenography has a number of critics from both the discipline and outside of it (Tight 2016). The main criticism appears to be at the active disregard for what language has been used in the data, instead focusing on the researchers' interpretation of what was said (Säljö 1994). Whilst this is certainly true, the concept of objectivity in interpretivist research, which the criticism appears to be about, should also be questioned. This also fails to appreciate the non-dualistic nature of the methodology and how subjectivity and objectivity are interlinked. For this research, all data are understood as constructed between the researcher and the participants and presented as experienced by the researcher (Åkerlind 2005). Therefore any meaning will always be how a researcher understood and processed the data and inherently lacks external objectivity. The aims of phenomenography are to present a collective analysis of individual experiences, and therefore the essence of the data is maintained despite the linguistic specifics being lost. The data are presented through the medium of the researcher, with them trying to reduce (through bracketing[19]) or acknowledge (through reflexivity) their preconceived ideas and individual impact on the final analyses.

Other critics of phenomenography (and other qualitative methodologies) express a concern for the lack of generalisability due to the small scales involved, as well as for the cognitive dissonance of the researcher when finding broad meaning whilst searching for an authentic individual understanding (Alsop and Tompsett 2006; Richardson 1999). This criticism highlights a lack of awareness for validity and reliability in qualitative research (Cope 2004; Sandbergh 1997). These criticisms also fail to understand the ontological and epistemological foundations of the methodology, with generalisability, via an appropriate 'power calculation' or otherwise, normally being desirable only in realist research (Sandbergh 1997).

Finally, there are those who are actively trying to improve the methods involved with phenomenographic data collection and analysis (Francis 1993; Richardson 1999;

[19] Bracketing is a technique used by researchers to reduce the impact of their presupposed ideas (Ashworth and Lucas 2000).

Cossham 2017). Clarifying instructions for how data are collected, or what is specifically required for an interview, has been cited as a simple way to improve the methodology, as currently the methodology allows for many acceptable variations, which potentially dilute the quality and validity of the methodology. This particular topic was debated at the recent Earli SIG-9 conference in Stockholm in 2022 (Bergmar 2022).

3.2 Methods

> "Methods are tools or instruments the effectiveness of which will only be maximised in the hands of a skilled, dexterous and creative user." (Watts 2014, 2)

There are many accepted variations in how phenomenographic data are collected and analysed (Ahmed et al. 2020; Pang 2003; Åkerlind 2005; Marton, Carlsson, and Halász 1992; Dahlgren and Fallsberg 1991; Säljö 1997; Han and Ellis 2019). The likely reason behind the amount of variation comes from one of the originators of the methodology. Marton himself keeps phenomenographic techniques purposefully opaque. In his 1986 landmark work *Phenomenography — A Research Approach to Investigating Different Understandings of Reality* he remarks that the details, especially when concerning the analysis, are somewhat lacking.

> "We cannot specify exact techniques for phenomenographic research… However, there is a way of proceeding with the task which can be described, even if it cannot be specified in detail." (Marton 1986, 42).

This suggestion on how to perform phenomenography risks losing any academic rigour or potentially validity. I therefore sought guidelines towards what constitutes valid qualitative research (Malterud 2001; Yardley 2000). Yardley describes 'good' qualitative research as being: sensitive to context; having commitment and rigour; being transparent and coherent, and having impact. Therefore, for this research and

for transparency, I followed the phenomenographic methodology as described by Stenfors-Hayes et al. in their paper *A phenomenographic approach to research in medical education* (Stenfors-Hayes, Hult, and Dahlgren 2013). I selected this approach to the methodology as it concisely described the methodology as well as acceptable variation, and had a focus on medical education. Stenfors-Hayes divided the methodology into data sampling and collection, and data analysis.

3.2.1 Data sampling and collection

Sampling in qualitative research is complex (Harsh 2011). Unlike in quantitative research, the researcher and their curiosity are not hidden in the process. Successful sampling and analysis in qualitative research should generate findings that are both clear and valid (Luborsky and Rubinstein 1995; Palinkas et al. 2015).

One of the goals of phenomenography is to explore understanding between participants and a phenomenon with the researcher seeking 'maximum variation' (Trem 2017). I used purposive sampling to select appropriate participants, with those who had experienced the phenomenon being considered relevant for the research (Bowden and Green 2005; Booth 1997). Practically, this was all doctors as managing uncertainty is a part of medical practice, but for the research, I was seeking those with a greater knowledge of medical education and the sampling technique increased the chances of finding data that is actionable and not simply insightful (Bowden and Green 2005). The number of participants is suggested to be sufficient to provide variation, but not too many to be overwhelming as the analysis is thorough (Trigwell 2000). Some recommend a pragmatic and convenient approach (Robinson 2014). A range of 10-30 participants in total was the suggested number, by both the research team and the literature, with a decision to sample new participants being considered by myself following each interview (described in more detail below) (Bowden 2005; Trem 2017).

As there is no universally accepted body of people to interview when discussing medical education in the UK, I attempted to interview those interested in medical

education as well as members of the Medical Schools Council (MSC) who describe themselves as the representative body for UK medical schools, as they seemed appropriate when generating findings concerning Medical Education ("Medical Schools Council" 2021).

Data collection in phenomenography also has many potential forms each with known strengths and weaknesses. Observation, think-out-loud methods (asking participants to verbalise their thoughts to a question), open and closed questionnaires, as well as semi-structured group and individual interviews, have all been used (Han and Ellis 2019). The selection of a data collection method largely depends on the depth of answer required as well as an estimation of the numbers required to observe sufficient variation. Semi-structured interviews are the most popular type of data collection, allowing for both depth and breadth of answers (Stenfors-Hayes, Hult, and Dahlgren 2013).

For this research, I began by sampling those involved with the creation of medical education ('Medical Educators' Chapter 4), followed by those who are subject to some of these creations ('Medical Students' Chapter 5).

The inclusion criteria for the medical educators were:

1) Having taught a wide number of medical students from all year groups - This was to allow for the educators who understood the difference needed in early and later medical school teaching and how teaching needs to differ.
2) Professional medical experience (working in clinical medicine as a doctor) - This was to ensure that there was an understanding of what clinical uncertainty felt like.
3) Experience of curriculum design or design of teaching interventions - This was to assure that any suggested teaching methods would be relevant and pragmatic rather than hypothetical.

Educators were sought from a wide variety of UK institutions, specialities and grades, with some already expressing an interest in the area and others recommended by the research team as having appropriate experience. Educators were invited to interview via email. Educators self-defined if they believed they fulfilled the inclusion criteria.

As stated above, I used semi-structured interviews as my data sampling technique for the educators. The reason for this particular data sampling technique was because it allowed interviewees to expand on any area they choose or follow any dimension they wish but still have enough guidance to answer the research questions, in a timely manner (Stenfors-Hayes, Hult, and Dahlgren 2013; Sherman and Webb 2004). The technique also allowed for questions to be sent in advance to allow participants to prepare and think of relevant examples. I encouraged participants to expand on what they said and to give anecdotal examples - two readily recognised techniques for improving data quality during interviewing (Abrandt 1997). The conversation continued until the participant felt that the line of enquiry had been exhausted and I felt that I had understood the perceptions of the participant (Entwistle 1997). In phenomenography, interview schedules tend to start with actual events and move on to hypotheticals and the style is said to be friendly and relaxed, whilst remaining neutral and non-judgemental (Stenfors-Hayes, Hult, and Dahlgren 2013; Ashworth and Lucas 2000). The focus was always on *the way* the participant described how they understood the phenomenon, with my knowledge and biases being excluded from the dialogue (Sandbergh 1997). This was done by me not contributing even if I felt there was something relevant to contribute, and maintaining the data collection as an interview and not a conversation.

I conducted two pilot interviews to hone the interviewing technique. Following each of these interviews, I discussed the process with the participant and amended my interview schedule accordingly (Appendix B). This largely consisted of altering the wording of questions so they were more neutral and removing certain questions so the interview did not feel rushed. The verbatim interviews can be seen in Appendix F.

In phenomenography, there are different approaches to when to stop seeking new participants to interview. Both data redundancy and data saturation are considered valid (Trem 2017). Data redundancy is defined as when categories (the main finding of the analysis - Section 3.2.2) start to repeat themselves in subsequent interviews and there are no new categories (Cleary, Horsfall, and Hayter 2014). Data saturation occurs when each question in the schedule is felt to have been fully explored (Trotter 2012, 399). Analysis typically occurs following each interview. I decided to use data redundancy as a guide as to when to stop seeking new participants as this approach appeared more popular amongst the phenomenography community and I felt that the concept of 'fully explored' as required for data saturation, was too subjective. Achieving data redundancy in qualitative research, like sampling, can be problematic (Nelson 2017; Braun and Clarke 2021). Indeed, it is likely that as you continue to interview, you will always generate some more data, of which it is up to the researcher to determine if sufficient data is 'new' and therefore worth continuing to interview (Low 2019).[20]

Data sampling for the medical students was in the form of Focus Group Discussions (FGD). To increase variation I targeted two different year groups, those who had just started medical school and were in their first term (year 1), and those who were closer to leaving medical school (years 4 and 5). The reason for having focus groups rather than one-on-one interviewing was to reduce my impact as the facilitator for the discussion, as I might be well known to the participants, as I am a teacher, tutor and examiner at the medical school. The focus group allowed for more dynamic interactions between participants and increased the variation in responses amongst groups who might not have any clinical experience of uncertainty or might not have felt comfortable exploring the topic alone. Students from the relevant year groups were invited to interview by email from the medical school. As suggested by the ethical review panel, an incentive was given for attendance. Students were able to

[20] Frequent conversations with my lead supervisor helped me feel more confident about when to continue and when to stop.

see the interview schedule in advance, refuse to answer any question and redact any of their own data before analysis.

The inclusion criteria for the medical students were:

1) In year groups 1 or 4 and 5 - To increase chances of variation of responses
2) Having no prior experience of clinical medicine (e.g. not working as a Health Care Assistant or other allied specialities)

The reasoning for having no prior experience is the student might have witnessed or had to manage uncertainty themselves, and the aim of interviewing students is to capture information from those less experienced with dealing with medical uncertainty.

3.2.1.1 Creating interview schedules

I created a semi-structured interview schedule, which is typical for the methodology, with the help of the research team and pilot interviews (Stenfors-Hayes, Hult, and Dahlgren 2013). The sample schedule was honed during the pilot interviews. Limited demographic details were taken, with the amount of time in education being the main variable for discerning the heterogeneity of participants.

There were a few areas of focus for the interviews with the medical educators. These were:

1) How did the individual conceptualise uncertainty?
2) How did they feel they learned to manage their uncertainty or how do they currently manage it?
3) Had the individual ever tried to teach uncertainty or related concepts to students?

4) Did they think this was possible and if so how would they recommend doing this?

5) When do they think students experienced uncertainty?

For the medical students the areas of focus were:

1) How did the individuals in the group conceptualise uncertainty?

2) When did they experience uncertainty during their training?

3) Had they felt they had been taught about uncertainty?

4) Did medical students feel that being taught about uncertainty was necessary and if so how would they want to be taught about it?

5) When did they think doctors experienced uncertainty?

The goal of question one concerning the conceptualisation of uncertainty was to enable the educators and students to describe how they thought of uncertainty as a phenomenon and to lay the foundation for the rest of the interview/discussion. The participants were encouraged to give memorable examples from their clinical or educational life that would be relevant to this research. As the methodology described, it is not up to the interviewer to define how the participant conceives the phenomenon but rather to give the participant the space to describe or explore how they interpret the phenomenon (Marton 1981).

For the educators, following what they felt about the nature of uncertainty, were questions aimed at exploring how they felt they learned to manage uncertainty or how they currently feel they manage uncertainty. These were areas that I felt had yet to be explored in the literature and would be important in understanding how uncertainty might be taught about, especially if any critical aspects of learning about uncertainty could be identified. Educators were encouraged to describe and reflect on an event or moments that they felt were pivotal in their understanding of medical uncertainty, or simply discuss why they felt they were able to tolerate the uncertainty they faced.

The interview schedule and topic guide used can be found in appendices B and C.

3.2.1.2 Collection and transcription

The interviews and focus groups were arranged for a time that was mutually beneficial to all parties and performed through Zoom for Education (an online video conferencing platform) as recommended by my research institute ("Zoom" 2021). The interviews and FGDs were recorded through an external device provided by the research department. Verbatim transcription of what was said is the standard approach taken with phenomenography, removing any hesitation or repetition (Trem 2017). The data was transcribed using the digital transcription service Otter.ai, and then I personally reviewed the transcripts with the audio for accuracy and corrected any of the mistranscribed text (Otter 2021). Only words spoken were transcribed. Other forms of communication, such as non-verbal communication were disregarded as data collection was online and therefore more difficult to interpret (as all interviews were slightly asynchronous and would have relied on accurate camera software/hardware, which could not be guaranteed). Alternative methods, such as fully performing the transcription myself, paying for a professional transcription service or an alternative piece of software were also considered but rejected to allow for a better understanding of the transcripts (bridging between the data and the analysis) and due to poor overall accuracy by the alternative software (Dortins 2002).

The transcript was copied into a word document. This document was sent back to the participant to allow them the opportunity to check the transcripts and remove any data they no longer wanted to include in the research. The transcript was then entered into the data analysis phase, as detailed below. A 'Google Sheet' (a type of spreadsheet) was the medium used for the analysis ("Google Sheets" 2022).

3.2.2 Data analysis

> "Phenomenographic data analysis involves a researcher constituting a relationship with the data which acknowledges the variation in the data and the undeniable influence of the researcher's prior knowledge of the phenomenon in the analysis process." - (Cope 2004, 7)

For this analysis, data were pooled into two different subgroups: medical educators and medical students (Chapters 4 and 5). The subgroups were analysed individually. The analysis itself was a seven-step iterative process (Dahlgren and Fallsberg 1991; Stenfors-Hayes, Hult, and Dahlgren 2013):

1) Familiarisation - I familiarised myself with the data, in the process of correcting the digitally transcribed transcripts and through reading the transcripts repeatedly.

2) Condensation - In each transcript, I highlighted statements that I felt represented what was being said by the participant in response to each of the areas of interest.

3) Comparison - Once I selected illustrative examples for each participant, I looked for similarities and differences between participants in responding to each question.

4) Grouping - I grouped these statements, noting their similarities and differences.

5) Articulating - I then captured the *essence* of each group. These were my conceptions of what the participant meant when responding to each question.

6) Labelling - I labelled meaningful essences as a category. These categories are described as derived by the researcher. I then reviewed each transcript looking for any *new* potential illustrative examples (repeating steps 1 to 6 with each transcript).

7) Contrasting - I compared and contrasted the categories.

This process is similar to other forms of qualitative analyses, such as Thematic Analysis as performed by Braun and Clarke (Braun and Clarke 2006). The main differences appear to be with the nomenclature (*themes* versus *categories*), the analysis of pooled data with the emphasis on variation (Cibangu and Hepworth 2016).

3.2.2.1 Unit of description: conceptions and categories

The categories derived from the data are the primary outcomes of phenomenographic analysis. They are created by the researcher from the conceptions of the participants and are meant to be an accurate representation of the data on a collective level (Booth 1997, 125).

> "Conceptions, which make up our unit of analysis, refer to whole qualities of human-world relations. They also refer to the qualitatively different ways in which some phenomenon or some aspect of reality is understood. When trying to characterise these conceptions, we use some categories of description. The categories are, however, not identical with conceptions – rather they are used to denote them." (Johansson, Marton, and Svensson 1985, 249)

When constructing a new category, I had to consider three key components (Han and Ellis 2019; Booth 1997):

1) The category must be unique and reveal something new about the phenomenon
2) The category must be logically related to other categories
3) Categories must be parsimonious[21]

[21] The word parsimonious is used here to mean as few as possible.

Typically between two and nine categories are derived per topic of enquiry, depending on the question and the data (Trigwell 2000). As stated earlier, the process was designed to be iterative leading to many rationalisations of the initial categories in trying to conform with component 3. Logical connections between these categories are made in the 'outcome space'.

3.2.2.2 The outcome space

In the outcome space, logical relationships between categories are identified and assembled (Marton and Pong 2005). Ideally, the outcome space and categories are constructed at the same time, however, there are practical difficulties with doing this, with researchers only being able to liminally process a finite amount of data (Åkerlind 2005). Categories can be arranged into a hierarchy. Hierarchies tend to be of an inclusive nature, where simpler categories lead to more complex ones (Walsh 2000; Tight 2016). This does not necessarily have to be in a linear fashion with some constructing branching hierarchies (Åkerlind 2005). Others have arranged categories in a chronological or temporal hierarchy, where the outcome space displays the participants' understanding of the phenomenon or how chronicity has affected the experience (Englund, Olofsson, and Price 2017). Again, this is not always the case, with other outcome spaces simply being a matrix or complex of categories, always with some logical connection (Marton and Booth 2013). Spaces can also be displayed as diagrams or tables (Bruce 1997).

A separate outcome space was created for each broad question. The outcome space was used to stimulate the discussion section of the thesis and draw conclusions.

3.2.2.3 Validity and reliability

The validity of all research should be challenged and measures put in place to improve the quality and acceptability of the work. Cope suggests that there are several measures required to ensure sufficient rigour with this chosen methodology

and therefore increase the validity and trustworthiness of findings (Table 3.2) (Cope 2004).

Table 3.2 - Measures taken to improve rigour in phenomenographic analysis - adapted table from (Cope 2004)

1	The researcher is to state their background - Even though the researcher is approaching the data with an open mind, their experiences will still contribute to their analysis. Acknowledging this allows the reader (and the researcher themself) to be better aware of the context
2	The researcher should state how the sample was chosen and why the purposive sample would be free of bias
3	There should be a clear justification of the interview schedule
4	The details on how data were collected free from bias should be given
5	The researcher should detail how the data was analysed with an open mind
6	The researcher should give the details of the data analysis process
7	The researcher should ensure that checks and measures are in place to check analysis is appropriate
8	Each category of description should include an appropriate quote or quotes
9	The results should be presented in a fashion which allows for scrutiny by others

I have reviewed these in one of my final chapters (Section 6.6).

In quantitative research, reliability relates to the reproducibility of findings (Booth 1998). For qualitative research, reliability relates to consistency and the use of methods and methodology (Leung 2015). This is why I have detailed my approach in this chapter and I used these methods consistently throughout my research. The relationship between me and the data was individual, and how other researchers might have interpreted what they had heard would vary from researcher to researcher and this is still considered both valid and reliable in the field (Cope 2004).

Reliability can also be demonstrated by discussing the appropriateness and logical connections between categories arising from the data with other members of the research team, in what is termed interjudge reliability (see point 7 in the table above) (Cope, Horan, and Garner 1998). Phenomenography has witnessed both group and individual analysis. Succinctly put:

> "While team analysis may seem inevitably more rigorous than individual analysis…the large number of existing phenomenographic doctoral theses indicates that high quality phenomenographic research can be accomplished as an individual researcher working largely on one's own." - (Akerlind, Bowden, and Green 2005, 94)

Simply put, because I have performed the majority of the research by myself, does not mean that my findings were not reliable. I was also both reflective, considering the appropriateness of the actions I took, and reflexive, considering my relationship with the subjects and how this impacted the data in an attempt to address further concerns relating to the data and its analysis (Reid et al. 2018; Leung 2015). Reflexivity is especially important in qualitative research as the data and outcomes are directly derived by myself, therefore understanding my own biases and reasoning allows readers enhanced insight into my findings. These sections can be found in the final chapter (Section 7.4).

3.3 Ethical considerations

As the research was performed with people discussing subjects that could potentially cause some distress, a number of particular ethical considerations needed to be made. This started as a discussion with my supervisors and this was followed by a review by the local ethical review panel at BSMS: The BSMS Research Governance and Ethics Committee (RGEC).

Two applications were made to RGEC. One concerning medical educators (ER/BSMS9E4C/2) and a second about medical students (ER/BSMS9E4C/3). Adequate provisions were recommended by the committee who suggested that an interview or focus group might cause some emotional distress. I was advised to contact student support in advance of any of the focus groups and to repeatedly signpost the service to students. The approved interview schedules for the two processes, consent forms, participant information sheets, recruitment poster and approval letters are available in appendices B, C and D.

The data collected will be stored for seven years as recommended by the Sussex Research Code of Practice, which is followed by RGEC, behind a password-protected device ("Sussex Code of Practice" 2021). Participants provided informed consent following being sent documents about the research. As well as providing written consent in advance of any formal research, at the start of each interview/FGD each participant was read the entirety of the informed consent form (by me) and given additional time to ask any further questions. Participants were asked to select their own pseudonym, so as to be able to identify their own quotes and the transcripts were sent back to participants following the transcription to allow them the opportunity to remove any contribution before being included in the final analysis.

3.4 Outcomes of the research and concluding thoughts

A goal of this research has been to increase the understanding of uncertainty in medicine and to discuss these implications for medical education. I selected a methodology which I believed would help me do this. There was also the potential to build a theory or 'a big idea' based on my research findings. There have already been theories in this research area. For example, the theory that uncertainty is an inherent aspect of medicine is a threshold concept. Although the formation of a grand theory was desirable, as this was highly exploratory research a more tangible goal was to

create a conceptual framework. Conceptual frameworks consist of more tentative ideas constructed around a complex phenomenon (Maxwell 2012). The frameworks could be used to increase understanding of uncertainty and how to teach students how to manage it. In the next chapter, I have interviewed and analysed what many in medical education believe about uncertainty. I have used this information to start to form initial answers to the research questions.

4 - Findings and Discussion - Medical Educators

In this chapter, I have described my findings from the interviews with the medical educators. They conceptualised uncertainty by listing the causes of uncertainty, and emotions related to uncertainty as well as problems with certainty. They felt they learned to manage their uncertainty from self-reflection and consideration of actions they had taken when uncertain, from the guidance and support of others, or from non-specific time and experience in clinical medicine. The medical educators were less confident when discussing when they thought medical students experienced uncertainty, linking it to the course structure, patient encounters or suggesting that students were simply always uncertain. Concerning questions about if uncertainty should be taught to students or not, the educators gave a range of answers, with arguments both ways. Overall they felt that any possible intervention should probably be placed when students had a better understanding of what medical uncertainty was, which normally meant recommending teaching nearer the latter end of the medical degree. The educators themselves had many different examples of how they had tried to teach medical students to manage medical uncertainty from podcasts to simulations. I used these findings to start to answer the research questions and make early recommendations on how to teach the management of uncertainty.

4.1 Sampling and demographics

As described in chapter 3, I invited participants to be interviewed if they had an interest in medical education, as well as experience in both curriculum design and teaching a range of medical students. Many of the people I interviewed were in senior positions where they could directly influence a medical school's curriculum. Those who responded to my initial email, or made suggestions about who would be suitable, were followed up. In total, excluding the pilot interviews, the research team

identified five educators to be approached, whilst four more agreed to be interviewed, answering the generic invitation email I sent to members of the MSC. Details about the institutions involved are given in Table 4.1. More details about the participants including the pseudonym chosen by each participant, years of teaching experience and which specialty they represented, can be found in Table 4.2.

Table 4.1 - Institutions

Medical Schools Represented
Barts and the London School of Medicine Brighton and Sussex Medical School Hull York Medical School Queen's University Belfast Swansea University College of Medicine University College London University of Lancaster University of Manchester University of Southampton

Table 4.2 - Pseudonymised participant information - Medical educators

Interview number	**Pseudonym**	**Years teaching**	**Clinical specialisation**
1	African Fish Eagle	11	Anaesthetics
2	Jolene	10	Elderly Care
3	Peloton	25	Anaesthetics
4	Turnip	24	General Practice
5	Mipha	16	Elderly Care

6	Max	7	Paediatrics
7	Robbin Collinson	5	Womens' health
8	Plato	32	Anaesthetics
9	Wilko	32	Respiratory medicine
10	Starfox	25	General Practice
11	Samuel	19	Orthopaedic surgery

An interest in medical education and experience were inclusion requirements but the area of clinical expertise was not. However, I found it reassuring that there was still a mixture of medical areas represented. This is because different areas of medicine might experience different types of uncertainty and might also have different reactions towards this, therefore purposefully excluding any specialty might mean that important data was missed.

The range in responses to the question "How long have you been teaching medical students?" varied with some respondents calling upon their entire medical life, even as medical students when teaching peers or drawing on informal teaching expected from most junior doctors, to others who only felt when they had accepted a formal teaching role could they say they meaningfully contributed to educating students. It is likely that relevant experience is very subjective. All educators felt they had taught a sufficient range of students and were able to give examples when I asked them to. The mean and median number of years teaching medical students was 19 years (range 5-32).

4.2 Findings

The full transcripts are available in appendix F.

4.2.1 How did educators conceptualise uncertainty?

I chose to start each interview with questions about how the educators conceptualised uncertainty. With such a large topic, my opening questions often led to clarifying follow-up questions from the educators, for example, from interview 5 with Mipha:

Jonathan Sadler: *"When I say uncertainty to you, what is conjured up? What does that mean to you?"*

Mipha: *"Um so what I was interested in... Is whether you meant like, uncertainty within the person themselves? … Or whether you mean uncertainty within medicine, so like not being sure of what a diagnosis is?"*

These follow-up questions from Mipha demonstrated just how many dimensions of uncertainty we could explore from a seemingly benign opening question. Mipha was describing uncertainty as either being something internal and in the mind of a person (subjective) or instead, being a property of the problem at hand, such as the inherent nature of uncertainty in medicine (objective). This division between subjective and objective uncertainties has been described elsewhere in the literature when trying to classify types of uncertainty (Han, Klein, and Arora 2011). Follow-up questions like these helped me understand how the educators conceptualised uncertainty even before they directly answered the question. On occasions such as these, I encouraged educators to discuss what they felt was more relevant, as it was for them to define their interpretation and parameters of uncertainty (Marton 1981).

There were five main categories that I derived from the data concerning how the educators conceived uncertainty (Table 4.3). The categories were: *causes,*

experience, emotions, certainty and *necessity.* The relevant reference quotes can be found in the associated outcome space (Table 4.3)

When considering uncertainty many of the educators described the *causes* behind what made them feel uncertain. Some of the time the educators were uncertain due to an identified knowledge or skills gap. Other times they felt uncertain due to not knowing the expectations of others - of patients, patients' family members or other hospital staff both more junior and more senior. The ubiquitous nature of uncertainty was the last identified cause, with uncertainty being unavoidable as it is ever present.

Uncertainty and thoughts related to *experience* was the second derived category. This included the uncertainty of every element of training when starting out and having no experience. This type of uncertainty, which is related to lack of knowledge, has previously been described as epistemic uncertainty (Simpkin and Armstrong 2019). Some of the educators also believed that an individual's experience of uncertainty would dissipate with increasing seniority. This description of uncertainty implies that all uncertainty is a purely subjective phenomenon.

Many of the educators linked their uncertainty to *emotion*al reactions. These included both positive emotions, such as excitement, as well as negative emotions, such as anxiety. Similar negative experiences towards uncertainty have been described previously, including uncertainty causing anxiety and burnout (Grupe and Nitschke 2013; Kuhn, Goldberg, and Compton 2009; Strout et al. 2018). As these negative reactions were common and were one of the justifications for this research, it is therefore not surprising that the participants discussed them.

When educators described their relationship to uncertainty they frequently referred to *certainty*. Educators linked certainty with confidence that actions were felt to be correct. Many saw this as being problematic as misplaced certainty might lead to actions which could unexpectedly harm patients.

The last category I derived, *necessity*, referred to the necessity of uncertainty in particular contexts. Firstly, in a clinical context, educators described the need to embrace uncertainty and not be overly certain, otherwise this might oversimplify the complexity of medical practice. Another educator described the necessity of being uncertain in the context of learning. They suggested that unless you are uncertain, you are not driven to learn as you have no need to overcome the uncertainty.

For this particular outcome space, I was unable to assign a hierarchy. This is not surprising considering the previous findings in the literature about how problematic uncertainty is to define (Bhise et al. 2018). I will discuss the reasons for this in the limitations section in the final chapter (Section 7.2.2).

Table 4.3 - Outcome Space for the conceptualisation of uncertainty in medical educators

Category	**Description**	**Illustrative examples**
Causes	Never taught therefore uncertain	"I think there's a lot of management stuff we're never taught." - Turnip
	Uncertain due to **expectations** of others	"I think there's societal expectations that feed into that really, I think we're probably less... I just wonder as a society if we're, if we're less tolerant of uncertainty that as maybe we once were, because our expectations of say, the medical profession are going up and up and up." - Max
	Ubiquitous	"I would say uncertainties out there all the time. It's just your perception of it and how you deal with it." - Plato
Experience	Uncertainty changes with experience	"So when you start out, everything feels uncertain." - Mipha "I imagine that the senior consultants don't experience uncertainty." - African Fish Eagle
Emotions	Emotional responses prior to or following uncertainty	"There's a balance of terror and excitement, because when you've done a job a long time, actually, the uncertainty is the fun." - Turnip "But it [uncertainty] definitely fills me with anxiety, particularly when I feel like their responsibilities, kind of like on my shoulders." - Jolene
Certainty	How to define certainty and its problems	"Certainty is, is that kind of internalised sense that you know you're right and that you are lacking in doubt." - Samuel "We come back from people where they've overestimated their certainty about things. That's almost like a terrible crime." - Max
Necessity	Describing how uncertainty needs to be more than acknowledged	"It's pretty fundamental that we… kind of embrace rather than ignore the uncertainty of practice. Because if you practise medicine in a way that kind of tries to be too reductive of uncertainty, you could potentially be quite successful on one level on a superficial level, but I'm not convinced that you'll ever do a truly good job." - Max "So every learner is... has to be uncertain to kind of learn, don't you if you were certain, you wouldn't learn?" - Mipha
Category	**Description**	Illustrative examples

4.2.2 How did the educators feel they learned to manage their uncertainty and how do they currently manage the uncertainty they face?

The next set of questions I posed were about how the educators currently manage the uncertainty they face in medicine and how they felt they had learned to do this. The analysis of these two questions resulted in the identification of three categories. These were that learning to manage uncertainty had come from Self (Table 4.4), Others (Table 4.5) or a combination of Time and Experience (Table 4.6). As the data was so rich I have presented the data at category level with an overview of the outcome space below this (Figure 4.1). Each of the main categories is presented as a table with relevant conceptions and illustrative examples. One response to these questions described an *inability* to manage uncertainty. Although this did not answer the question it was still insightful and I have included it below, labelled Unclear (Table 4.7).

The Self category related to the idea that learning how to tolerate uncertainty or how to manage uncertainty were internal processes. The conceptions were: *anticipation, knowledge, confidence, safety netting* and *reflection* (Table 4.4). The category is presented in a temporal hierarchy, with early conceptions occurring before an episode of uncertainty and later ones occurring either during or after.

Anticipating possible outcomes and preparing for these outcomes was a method of managing uncertainty. The uncertainty described when discussing the *anticipation* concept was similar to that of previously described aleatoric uncertainty, where all the likely outcomes are known and the uncertainty is about which one will occur (Simpkin and Armstrong 2019). The concept of being uncertain due to a lack of *knowledge*, or having epistemic uncertainty, was also discussed. Here, an educator described how they used the academic literature, always keeping up to date with current relevant journals, to abate or reduce their epistemic uncertainty.

Acting with *confidence* was another way suggested to me about how to manage uncertainty. This concept suggested that patients or colleagues expect a level of certainty from their doctors, which might not be warranted given the inherant uncertainty of the situation or of the doctor. Even if that doctor felt uncertainty, they should act confidently rather than express their uncertainty. The conception related to the previously described cause of uncertainty being the expectations of others (Table 4.3).

Safety-netting is a technique for planning for multiple eventualities and communicating these with patients and has been already identified as a way of managing uncertainty (D. Jones et al. 2019). It is no surprise then that this concept was described by a number of educators as the way that they tolerate uncertainty. Safety-netting was only possible if the educator was able to *anticipate* the many potential outcomes which linked these two concepts (anticipation occurring before and safety-netting during a consultation). Again, being able to successfully safety net meant that the educator had knowledge of what outcomes were possible, which further described the importance of accepting aleatoric uncertainty (Simpkin and Armstrong 2019).

Reflection was the final concept linked to the category of Self, describing how educators believed they learned to tolerate uncertainty. The reflection involved the educator returning to an uncertain event and considering how they could have managed the situation differently. Accepting that mistakes can occur when uncertain also helped some educators improve their management of uncertainty, or at least have more confidence in their actions.

The majority of educators believed they did not struggle with uncertainty and some educators did express the opinion that their abilities to deal with uncertainty would continue to grow (from interview 2 with Jolene):

“As we know that the more experience we get the more atypical things we see which then add more uncertainty [understanding] as it were. Until you reach a point where you've seen all those like atypical experiences and then you feel certain of them. I guess, like when you're like 60.” - Jolene

Table 4.4 - Category - Self

Conception	**Description**	Illustrative examples
Anticipation (before)	Describing uncertainty as being aleatoric in nature and how to manage this	“To my way of thinking when you talk to the patient, initially, you're, you're making a mental model in their [your] head of their psychology, their physiology, and what you're going to do, and you're kind of predicting in your head, well, if I do this, and this drugs, this is going to happen. And you know, if they're sick, then you think, ‘Okay, well, A, B, or C might happen.’” - Plato “What you're describing is sort of branches that used to not have any branches, you know, this was going to happen then and this was going to happen, and then if something didn't happen, that caused your stress, and now you're saying this is gonna happen, and then these three things might happen, and then you know where to go from there.” - Mipha
Knowledge (before)	How to use scientific knowledge during consultations when uncertain	”And in terms of uncertainty, I think the most important thing for me is keeping up to date. So reading the latest literature.” - Robbin Collinson
Confidence (during)	Being sure to project confidence even if uncertain of correct response	“[How to answer when uncertain] All of those things come from just not having that, that absolutist knowledge, which, again, is really common, but we kind of 'fake it till we make it'.” - Samuel “[When interacting with patients when uncertain] I think it's actually my coping strategy is to be a bit more blasé about it.” - Jolene “[Discussing plans when uncertain with nursing staff] There are times when it can make your life easier just to present the veneer of certainty.” - Max

Safety netting (during)	Management of uncertainty through safety netting	“What you're doing is try to plan for the best outcome, but make sure that if the worst outcome happens that you've got a plan in place to deal with it.” - Starfox “I can still safely go down this path with these safety nets in place, for example, viewing the patient in an hour.” - African Fish Eagle
Reflection (after)	Reflecting on own practice and accepting mistakes	“I think all of it comes through experience and reflection on that experience.” - Mipha “[Reflecting when uncertainty was managed poorly] The moment you become quite Zen about cocking up or saying I don't know is the moment training becomes a very different experience.” - Samuel
Conception	**Description**	Illustrative examples

Others

Along with the concept that the management of uncertainty was learned by being introspective, came categories that described how people learned from or with others through *observation, supervision, discussion* and the existence or creation of *safe spaces* (see Table 4.5).

Direct *observation* of others was how a few of the educators believed they learned to manage their own uncertainty and was already a well recognised part of medical learning (Turner, White, and Poth 2012). The educators described how witnessing how others interacted when managing uncertainty shaped their own future interactions with patients, with educators attempting to mimic behaviours they considered successful and rejecting behaviours they considered less successful. Wilko in interview 9 described the importance of shadowing:

> *"[During shadowing] It's not the imparting of didactic knowledge, you know that has to happen, but it's neither here nor there. It's watching how people interact with other people, with colleagues and with patients and what you choose to take on board."* - Wilko

Following on from observation came the conception *supervision*. One educator described how supervision became more distant as a student became more experienced and confident, and was ultimately up to the student to request supervision.

Discussing identified uncertainty with peers was another method described by the educators as how they learned to manage their uncertainty. This could be for reassurance that the action taken was appropriate or be more inquisitive about how others might have managed the situation. Within this concept, I discovered that different specialties within medicine might discuss uncertainty differently, depending on how accepting the educator's department was about addressing uncertainty.

The final concept within this category was the creation of an environment within the work *space* that allowed anyone to manage uncertainty without the threat of repercussions should their management not be considered optimal. A safe culture can be part of a systems approach to medicine, where the 'system' rather than the individual is to blame for hospital incidents (Steiner 2006). This systems approach was suggested by educators as a way of learning how to manage their own uncertainty.

In the outcome space, conceptions were arranged into an inclusive hierarchy from more individual actions (although involving others) to the way departments were organised. Each of the conceptions could be included within the subsequent conception.

Table 4.5 - Category - Other

Conception	Description	Illustrative examples
Observation	Witnessing how others manage a situation and reflecting on their practice	“Seeing other people do consultations. I think what I realised is sometimes I think the way that consultants handled things [when uncertain about the outcome] wasn’t ideal… When they speak to a patient, you're just thinking, ‘Oh, that sounds awful’.” - Robbin Collinson
Supervision	Checking your response with those more senior	“As a junior registrar… you'd make a plan. And then you'd be like, "hold on a sec, let me run this past the consultant and check they're, okay (the plan)." And then as you become more senior, you're like, ‘Actually, I can make this decision. And as long as I can stand by it.’” - Robbin Collinson
Discussion	Discussions with peers	“These are people [peers] I really trust their clinical judgement on. And then I'm like, Okay, yeah, this is what I think [when told how situation was managed], [and] they think I've not missed anything massive.” - Turnip “I think the most I've learned [about managing uncertainty] is through discussing with colleagues [at regional training days].” - Jolene “MDT [Multidisciplinary team] trauma meetings, discussions in clinic, conversations in coffee rooms, can be, if done properly, just great learning experiences.” - Samuel “Every specialty has different ways they then talk to their colleagues about uncertainty like some have like M&Ms [Morbidity and Mortality] when it's really gone badly, or some just have like after action reviews. Some just have like coffees where they're able to talk about things that were like tricky, really, really informally.” - Jolene
Safe space	System is responsible for actions not individuals	“I think our department's really helpful because everyone sort of bought into the system's approach of mistakes.” - Mipha

Time and Experience

Time and experience were commonly repeated conceptions when discussing how educators felt they learned to manage uncertainty in medicine (Table 4.6). Each educator mentioned one or the other or sometimes both as a reason they felt they could manage their uncertainty. The differences between time and experience should also be noted, with one educator clearly delineating the two when describing the 'experienced (having practised for a long time) non-expert'. The 'experienced non-expert' was described as an individual who you would expect to be able to manage uncertainty due to the amount of time they have been practising, but due to only experiencing a narrow work type, they are only able to manage the conditions they know well (from interview 3 with Peloton).

> *"I mean the worry is that you get people who have 20 years experience, but just did the same thing again, and again. The 'experienced non-expert'. And they're the ones who worry about their flexibility of thought and abilities to deal with uncertain situations and work their way through them."* - Peloton

This line of reasoning suggests that training to manage uncertainty was relevant throughout a medical career and that a doctor might not be aware of what they do not know, which again related to uncertainty being a threshold concept (Gaunt and Loffman 2018). This description by Peloton also helps stop the conflation of time and experience and describes how not all time and experience are equal for learning.

The conceptions for this category were: *time, pre-clinical, during training* and *experience*. *Time* and *experience* were fairly non-specific conceptions, whilst *pre-clinical* conceptions suggested that experiences prior to clinical training would affect how students manage uncertainty during medical training. The *during training* conception described clinical experiences that occurred on placement or as a junior doctor being the only ones that were relevant to learning how to manage uncertainty.

Table 4.6 - Category - Time and Experience

Conception	**Description**	Illustrative examples
Time	Time itself has allowed for better understanding of uncertainty	“I think time probably.” - Max “I suppose as you get older, you get more comfortable with uncertainty.” - Plato
Pre-medical	Pre-medical experiences of uncertainty and having to manage these	“You've had a lot of adverse childhood experiences, and there's also people that have had too many that will just tolerate shitloads of uncertainty.” - Turnip “There's your early experiences, how you've learned to manage things where you're not in control, or the things that you think, or something bad could happen here.” - Max
During Training	Experiences or memorable moments early on in your training, which you call upon later	“There's also adverse medical experiences that you have as a, when you're learning as a *baby* [medical student], you know, you're learning this thing of medicine. And those, those very transformational experiences.” - Turnip “I think problem solving experience in the on-call setting, does, sort of, that you're always dealing with multiple things dealing with situations you haven't encountered before, maybe there is some sort of experience in the problem solving setting that helps.” - Jolene
Experience	Experience of uncertainty leads to acceptance	“Have enough experience, have enough insight, to know that actually, this is how practice is, you know, that this is intrinsically uncertain.” - Max ”If there is diagnostic uncertainty, then I take it for granted [having had enough experience] that that is because there's diagnostic uncertainty rather than because I'm not good enough to get to certainty.” - Mipha
Conception	**Description**	Illustrative examples

Outcome Space

Above are the different conceptions and categories that contributed to how doctors believe they learned to manage or how they currently feel they manage their uncertainty. I have arranged them into a single diagrammatic outcome space, including the original conceptions. In the diagram, I have included the temporal element showing how each conception relates to the timing of the uncertainty (Figure 4.1).

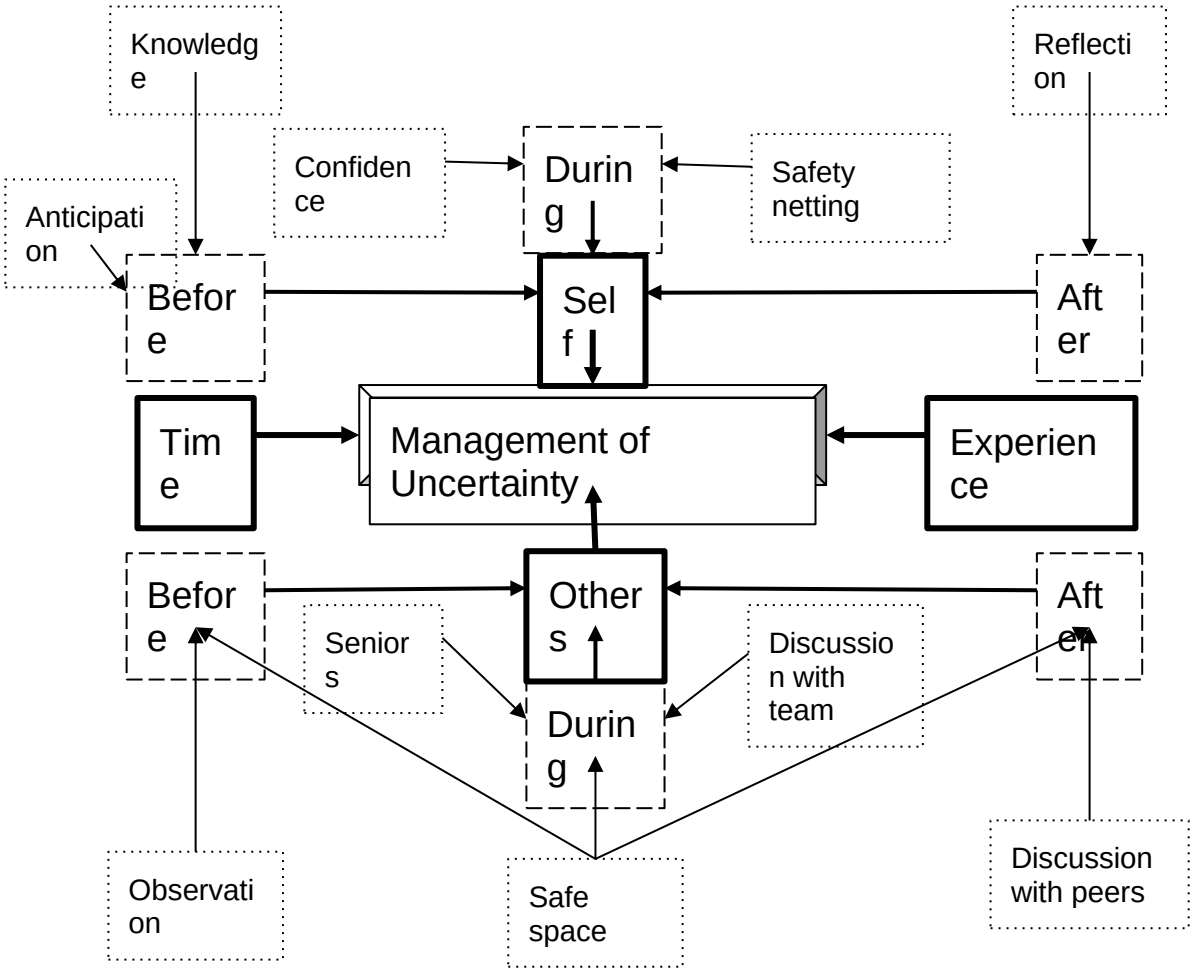


Figure 4.1 - Diagrammatic outcome space demonstrating how educators felt they learned to or currently manage uncertainty (Solid boxes are categories and dot boxes are conceptions, arrows show an association between conceptions, time and categories)

Unclear

There was one final conception that did not suit any other category but was still important in how uncertainty was (or was not) managed and therefore I felt the essence still needed to be captured (Table 4.7). The conception was that management of uncertainty was situational or sometimes not possible. The educators described that some days, they were unable to manage uncertainty due to other life stresses such as being hungry or tired, or them being unable to find a solution. This conception highlighted that managing uncertainty should not be taken for granted even by experienced physicians and these conceptions emphasise that management of uncertainty is a skill that requires effort and attention.

Table 4.7 - Category - Unclear

Conception	**Description**	Illustrative examples
Situational	Not always able to manage uncertainty	"Managing uncertainty takes a certain amount of RAM to process, like cognitive power. And there are times in your day, times in your life, when you do have that cognitive power and times in your life that you really don't." - Turnip "[When discussing how to manage uncertainty] There are very few occasions where this [any solution] is 100% always the answer." - Samuel

4.2.3 Uncertainty in medical education

After questioning the educators about themselves the rest of the interview was about their students and uncertainty. The questions included: When did their students experience uncertainty? Should uncertainty be taught at medical school? Had they ever tried to teach uncertainty? As well as where they would place any

teaching of uncertainty in the medical student journey and hypothetical ways uncertainty could be taught about.

4.2.3.1 When do students experience uncertainty?

I asked a variety of hypothetical questions to the educators about when they felt medical students experienced uncertainty. There were four categories derived from the data collected (Table 4.8). These were uncertainty related to the *course*, the *individual* and then uncertainties that were either *tangible* or *intangible*. How these conceptions related to each category within the outcome space can be seen below in Figure 4.2.

Students might be uncertain due to the *course* structure. This could be due to logistics (e.g. where and when they are meant to attend clinical experiences), or due to assessments they would face, or bigger questions such as how they were going to complete their Damocletian logbook?

Individual uncertainties was another conception described by the educators. These included personal uncertainties such as if they are expected or wanted when shadowing other healthcare professionals. There could also be uncertainty due to the etiquette expected from patients when students wanted to learn but not to impose. Educators also expressed the feeling of being deserving of a place at medical school and concerns about what the students' career might involve.

These categories could be related to *tangible* and identifiable aspects or *intangible* aspects. A tangible aspect would include identifying a clear time that the student would be uncertain. For example, the first time a student encounters a patient, they are likely to be uncertain about how to manage the entirety of this situation. Intangible aspects included responses such as 'all the time', or uncertainty that was being hidden from the medical student such as externally imposed changes to the curriculum (for example by the GMC) or uncertainties that are being hidden from

students by educators who are unclear how to express their uncertainties (from interview 5 with Mipha):

> *"[When expressing uncertainty in front of students] I think people fear that novice teachers fear that [expressing uncertainty] because it makes it look like you don't know what you're doing."* - Mipha

Some educators chose not to answer these hypothetical questions (from interview 3 with Peloton):

> *"I am not sure. I mean, I don't I don't teach a lot on the wards, for instance, in the primary specialties. So it's a bit hard to answer that one."* - Peloton

Table 4.8 - Outcome space related to when medical educators feel that students experience uncertainty

Category	**Description**	Illustrative examples
Course	Assessment, Logistics and Timetabling and Logbooks. Uncertain what expectations teaching staff will have about students	"They [students] obviously have uncertainty around assessments." - Starfox "[When discussing the logbook] Our students go on and on and I'm sure other students at other places do about getting clinical skills and getting those signed off." - Starfox
Individual	Believed knowledge gap, when stressed, existential self-doubt including whether they should be at medical school	"I think it's uncertainty about whether they are deserving of their place in medical school. Uncertainty, whether they'll make the grade… Uncertainty about whether they really want to be a doctor at all." - Wilko "[When attending clinics as a student] Will people know I'm coming? Am I wanted?" - African Fish Eagle "I think they're uncertain about the future. I think they're uncertain about [their] career path, I think they're uncertain about all kinds of things at quite a core level." - Samuel
Tangible	Uncertainties that can be identified	"I think as soon as you start having that patient encounter, and you're starting to then communicate it, that's when uncertainty really kicks in." - Robbin Collinson "And I suppose the first bit of uncertainty around all of that comes from the differential diagnosis, because the differential diagnosis is uncertainty, isn't it?" - Starfox
Intangible	Difficult to attribute exactly why students were uncertain, or hidden from students	"They're in the position of uncertainty all the time in a medical school." - Turnip "Oh, like, every, like, every minute of it." - Jolene "I would suggest, all the time." - Samuel "So I would say, well, uncertainty is evident around us all the time." - Plato "They're in the position of uncertainty all the time in a medical school, or we don't know what's going on with with exam or the UK FPO has messed up. We don't know what's going on. How stressful is that?" -Turnip

		“[When doctors are teaching students in clinical situations] And we should like we probably should signpost it [own uncertainty] more of trying to show that actually, we're not as confident as we look is the facade that we're trained to put on.” - Jolene
Category	**Description**	Illustrative examples

The conceptions described above are highly interlinked and there is much overlap between them. For example, the conception 'Uncertainty is hidden from students' is as much intangible as it is related to the course. These interconnections are displayed below in a diagrammatic representation of the outcome space (Figure 4.2).

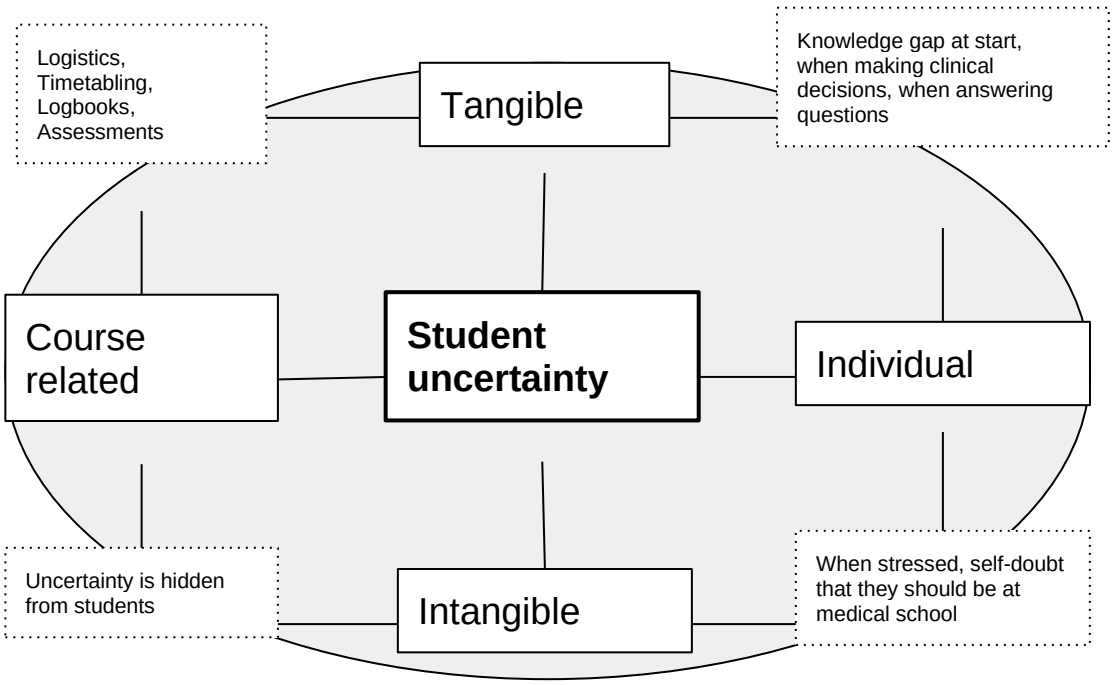


Figure 4.2 - Diagrammatic outcome space relating to when students are thought to experience uncertainty. The grey circle represents the entirety of student uncertainty. The solid boxes are categories and dot boxes are conceptions identified from the data. The lines are connections between the categories and the conceptions

4.2.3.2 Should uncertainty be taught to students?

I then posed the relatively closed question about whether uncertainty, in any format, should be taught to students either directly or indirectly (Table 4.9). There were two opposing viewpoints: *Yes* and *No*. I derived five categories around the conceptions from the educators data, including conditional responses (*yes but* and *no but*) as well as one educator who was unclear if it could be taught or if they indeed had all the answers (*don't know*).

Unlike for previous questions, there was a much clearer variation in response, with some educators who adamantly thought uncertainty should be taught throughout medical school and having the same amount of passion as others those who were vehemently against any teaching. The three declination categories (*don't know, no but* and *no*), all appeared to have pragmatic reasons as to why uncertainty could not or should not be taught about. The *don't know* category highlighted again how complex a concept uncertainty was, and overall confusion about how anyone can learn about it or indeed if the educator was the right person to teach students about uncertainty.

Table 4.9 - Outcome space relating to if students should be taught about uncertainty

Category	**Description**	Illustrative examples
Yes	Students should be taught about uncertainty	"[When asked if uncertainty should be taught directly] I think we should. I think it's a core competency. I think we should normalise. And we should normalise that not knowing the answer is okay. And that not only is not knowing the answer, okay but we should fundamentally be okay with other people not knowing the answer as well." - Samuel "[When asked if uncertainty should be taught directly] Yeah, I definitely do, I think. And since then, the clinical reasoning stuff, and also other things I've read about clinical reasoning." - African Fish Eagle
Yes but...	Students should be taught about uncertainty, but with some conditions (such as after some clinical experience)	"[When asked if uncertainty should be taught] Probably. But probably not too early, or just because it is quite a mature concept in some ways." - Starfox "[When asked if uncertainty should be taught] Once the medical student gets to a certain level where they might have been exposed to stuff. Maybe it is something more formal through cases or through examples or something. Definitely not just talking about the concept." - Jolene
Don't know	Educator is unsure if uncertainty can be taught	"[When learning about uncertainty] I just don't know whether it's possible to accelerate that process? Or do it differently? And I don't know if I've got it, right." - Wilko
No but...	Uncertainty is something learned implicitly and is already taught about	"It's really important principle for me if you teach people how to take a history, how to deal with conflict, how to make a diagnosis, how to do this... separately, that's great. They can all do that separately. But that's not the point. You've got to do all those things at the same time." - Plato
No	Uncertainty cannot be taught	"I'm not sure it's a goer really. I mean how are you going to develop a curriculum for it? You know, what outcomes are you going to have? How you gonna assess it for instance?" - Peloton
Category	**Description**	Illustrative examples

4.2.3.3 Have you ever tried to teach the concept of uncertainty to medical students?

Having reasoned whether or not there should be teaching concerning uncertainty at medical school, I then asked the educators if they had actually tried to teach the concept to medical students. Below is a list of the nine examples given (Table 4.10) followed by the associated outcome space (Table 4.11). The examples were: Podcast, Lecture, Simulation, Clinical Debrief, Clinic, Being explicit on ward round, Frequency gambling, Case presentations and Giving students a long time with patients. For the examples given, I have presented them in a hierarchy from least to most student involvement. In the early examples, student involvement was optional such as creating a podcast for students to listen to. Whilst in the later examples the student was participating more with their learning. I have chosen not to include associated quotes as the essence of what was said was already captured in the description and the reference quote added little to this (Appendix E for related quotes and analysis). This is an accepted way of displaying data in phenomenography (Akerlind, Bowden, and Green 2005).

I will describe both Clinical Debrief and Frequency Gambling as these were fairly novel teaching methods to me. Clinical Debrief appeared to be similar to a Balint group, where any topic could be discussed and members of the group are invited to suggest responses, with queries going to a more senior role (for Clinical Debrief this was a GP) (Yazdankhahfard, Haghani, and Omid 2019). However, discussing uncertainty was not explicitly the reason for the group, and there were no clear learning objectives from the group other than to provide a safe space for students to learn in.

Frequency Gambling was described as teaching about the management of uncertainty during an acute clinical situation (such as a patient becoming hypoxic on emergence from general anaesthesia). Here, the educator would describe their rationale for why they were reacting in a certain way, considering all possible

problems and managing them with the most likely and most dangerous problems being addressed first, followed by continual reassessment.

Table 4.10 - Examples of different methods used to teach students about uncertainty

Example given	**Description**
Podcast	A podcast between senior consultants discussing how they managed uncertainty in an 'interesting' case
Lecture	A lecture to final year medical students about doctors making mistakes, why and what they did after that A lecture on differential diagnosis
Simulation	A collection of simulations, escalating in difficulty and uncertainty Hire actors and give them random symptoms and ask students to take medical histories from them, to allow students to face true uncertainty
Clinical Debrief	A regular weekly session where students in small groups (<8) discussed stressful clinical encounters with a GP. GPs were asked to focus on student uncertainty and how to manage this.
Clinic/GP Surgery	Asking students to present cases in clinic and exploring uncertainty with them
Being explicit when on ward rounds	During ward rounds with students, remarking when there is an area of uncertainty and what sort of uncertainty
Frequency Gambling	During times of uncertainty, demonstrating frequency gambling, a clinical management technique that manages a number of possible outcomes with the most frequent being the most likely
Case presentations	Formal case presentations to a group with questioning focusing on uncertainty
Giving students a long time with patients	Allowing students enough time (2 hours suggested) to take a very thorough patient history and encouraging them to explore all avenues of uncertainty with the patient.
Example given	**Description**

I analysed these examples and generated two divisions and four categories (Table 4.11). The first division questioned the nature of the teaching dividing teaching between implicit or explicit examples. Was uncertainty the main topic for the educator or did this just happen to be one of the many areas that are uncertain such as differential diagnosis or clinical reasoning? The second division was between formal and informal teaching. Was this teaching that was planned and compulsory or was this something that occurred whilst the student was on a placement or shadowing, such as opportunistic medical education? The nine examples each fell into one of the four categories: *Formal Explicit*, *Formal Implicit*, *Informal Explicit* and *Informal Implicit*.

Table 4.11 - Outcome space relating to different ways uncertainty has been taught

Formal Explicit	**Informal Explicit**
Simulation Case presentations	Podcast In a Clinic Ward rounds focusing on uncertainty 'Frequency Gambling'
Formal Implicit	**Informal Implicit**
Lecture Clinical Debrief	Giving students a long time with patients

4.2.3.4 Where does uncertainty in medicine fit in a medical undergraduate programme?

After I had asked the educators if they believed that uncertainty should be taught, I followed this by asking where the teaching best fits within the undergraduate medical curriculum. There were differing opinions concerning whether an intervention should be targeted at undergraduates. Of those who believed it should, there was little consensus as to where it should be in the curriculum. For this outcome space, I derived four categories from the data: *throughout, having*

experienced uncertainty, clinical years and *graduates* (Table 4.12). The categories have been arranged into a chronological hierarchy, with earlier categories being aligned with earlier student experiences and later categories with later student experiences.

The *throughout* category included concepts that teaching about uncertainty was always relevant and that it was always appropriate to teach students about uncertainty. Educators suggested that as uncertainty was inherent, rather than hide students from the phenomenon, students should instead be taught about it from the start of medical school until they graduated.

The next category, *having experienced uncertainty*, had a reactionary element towards when uncertainty should be taught. The central premise was a student needed to have experienced some uncertainty before any intervention would be relevant to them. The timing or type of uncertainty expected from the educators differed depending on how the educator thought the student would encounter uncertainty. This meant that some educators felt that the students would experience uncertainty from the start of the course, and therefore should have guidance on how to manage this uncertainty then, whilst others were less specific. The diverse range of curricula, both experienced by the educators when they were medical students and also being used in their current places of work, only further clouded any precision for an intervention.

The next category in the outcome space was in *clinical years*. The category related to students only being taught about clinical uncertainty once they had definitely been exposed to uncertainty. The educators believed that clinical uncertainty would be a hard concept to understand without having witnessed or managed any of it. This again implied that clinical uncertainty was a threshold concept, where without encountering any clinical uncertainty, it was hard to imagine.

The final category, *graduates,* was expressed by educators who did believe that people could be taught about uncertainty, however, the most appropriate time to

do this was following medical graduation. This could be related to or an extension of the prior category, which allowed for the experience of uncertainty before the attempt to teach about it. One educator in particular was concerned that learning about clinical uncertainty when the students would be uncertain about everything, made it a difficult premise to grasp. Here, the educator alluded to the differences between epistemic and aleatory uncertainty and how a student's knowledge might help them make a transition (Simpkin and Armstrong 2019). With students having epistemic uncertainty, not knowing what they should and should not know, and the management of clinical uncertainty being related to aleatoric uncertainty, where the possible outcomes are known but the individual is simply unsure which one will occur.

Table 4.12 - Outcome space relating to where uncertainty fits in medical school

Category	**Description**	Illustrative examples
Throughout	Uncertainty is always relevant and therefore should be taught throughout medical school	“I think, [I’m going to turn] the question on its head and say, there's never not a good time to do it. Okay, so you'd be doing it all the time.” - Wilko “The whole way through, I think, it is patient safety issue.” - African Fish Eagle
Having Experienced Uncertainty	Students should be taught about uncertainty once they have encountered the uncertainty doctors face	“So trying to help them from year one go, you've got a problem? What do you do? How do you make a decision? Why are you deciding something different to me?” - Turnip “I feel like you have to have some kind of experience.” - Jolene
Clinical Years	Students should be taught about uncertainty in the latter part of their education	“I think if you've not got the clinical placements just yet, then I think it's a bad time. Because I think it just goes over their head and they're not interested. And it's too difficult to take on board. It's unrelatable.” - Robbin Collinson
Graduates	Understanding uncertainty is a postgraduate area	“It's particularly challenging for students because it's all very well for me to embrace the concept of uncertainty after 30/40 years as a, you know, post-graduation. It's really not alright when you're just uncertain about everything. So enabling them to understand uncertainty in the context of being uncertain about everything is very challenging, I think.” - Wilko “It might be easier as they're maturing as trainee clinicians, that it's easier for them to, to reflect where they've seen it.” - Starfox
Category	**Description**	Illustrative examples

4.2.3.5 How would you teach medical students about uncertainty?

My final questions were about the possibility of how the educators could teach students about uncertainty. I generated an outcome space with four main categories each with two opposing subcategories (Table 4.13 and Figure 4.3). The four categories were: *focus* (student or staff), *placement* (in or out), *frequency* (discrete or longitudinal) and *obviousness* (explicit or stealth).

The first category concerned the subject of *focus* for any intervention. Either the intervention focused on the students or the staff responsible for educating the students. For the student focus, examples were given suggesting that students should be encouraged to experience uncertainty in a psychologically safe space, or be probed during presentations until they admitted or organically experienced clinical uncertainty. Examples for interventions which focused on staff included recommending that staff admit when they were clinically uncertain to allow students the ability to experience how normal uncertainty is. Being able to understand what clinical uncertainty actually is, by having it pointed out by staff, allows students to witness how the uncertainty is dealt with in real time.

The second category concerned the physical location or *placement* of any potential intervention. The educators differed with their opinions of where the students should encounter uncertainty. Some of the educators suggested that uncertainty needed to be witnessed in placement, while the medical students were on their clinical attachment or shadowing doctors. Others suggested that there were a variety of different ways uncertainty could be taught, such as in lectures, simulation or other places away from clinical placements. Simulation and other out of placement techniques have already been used to teach about uncertainty (Bentwich and Gilbey 2017; Golden et al. 2018; Fernandez et al. 2016; Liou et al. 2019; Scott et al. 2020).

The *frequency* of any intervention in a curriculum was another category derived. There were educators that stated that only a single intervention was required but the timing of the intervention was important. For example, one educator suggested

that the optimum moment would be when a student found uncertainty teaching both relevant and meaningful. When this would be, was different depending on which educator was being asked (for more see Table 4.12 - outcome space relating to where uncertainty fits in medical school). This concept, that students will not be ready to understand uncertainty until a certain point, related again to uncertainty being a threshold concept and a correctly placed intervention allowing a student to transcend the threshold from not recognising the importance or understanding of uncertainty, to comprehending what is required to master it. Other educators thought a more longitudinal approach was necessary, with students visiting and revisiting the concept a number of times throughout their training allowing for, and indeed expecting a more gradual transition.

The final category was how *obvious* uncertainty should be as the subject of the teaching. For this category, educators were divided between making the teaching about uncertainty explicit, allowing the students to appreciate and understand how unavoidable uncertainty is, or hiding uncertainty deeper within the teaching. Teaching about uncertainty through stealth was considered relevant, as certain educators believed that medical students might have rejected the explicit teaching of more abstract professional skills.

Table 4.13 - Outcome space relating to ways of teaching uncertainty

Category	**Description**	Illustrative examples
Student-focused	Design teaching around the student experience, such as case presentations or creating an environment where students can safely explore options when uncertain (E.g. On a ward or simulation)	"So in terms of teaching uncertainty, through experience, really, through contributing to care, but in a way that, you know, gives you enough involvement that you kind of, you get immersed in the realities of it, but in a way that's psychologically safe." - Max "[At a case presentations] ideally, to get to the point when, at the end, you're asking questions, where actually the answer... there isn't a very good answer to those things." - Plato
Staff-focused	Re-educate those with student-facing roles to normalise the expression of uncertainty, or describe the problem to those who teach or integrate it into more formal teaching	"[How to normalise uncertainty] Faculty Development for clinical teachers and clinical teachers really being anyone that teaches medical students on placement." - Max "You try to work with your clinical teachers. Encourage them to remember it when they're talking about a case presentation, discussing cases, diagnostic reasoning, therapeutics [to express their uncertainty]." - Mipha
In Placement	Uncertainty should be addressed in placement (such as when shadowing a doctor) when experienced by doctors	"Uncertainty is a product, predominantly of the real world of medical work, really. So we got to teach uncertainty within that world." - Max "[How to best teach about uncertainty] One student following a clinician, that's a really good teacher, and in the clinical environment, and just doing shadowing." - African Fish Eagle
Out of Placement	Uncertainty being taught away from a clinical environment	"If we can teach it in a place removed from the workspace…removed from the frontline of the pressure of the decision making." - Turnip "[A] Mixture of really obvious things like role modelling and other things like sim and talks. And it should be part of the curriculum not only in terms of, yeah, having some lectures about it and all the rest, but also about the medical schools living their values." - Samuel
Discrete	A single intervention at the right time through training	"[When teaching about uncertainty] It's about trying to, at the right point, teach students the ways of managing, you know, ways of managing it, and also seeing if people could get some self awareness." - Starfox

Longitudinal	Continually approaching uncertainty at different times during medical school	“It feels to me like it should be something longitudinal or like I think you're saying that I think you need to say, this is patient safety teaching, or I'm teaching you this or we're going to do this…” - African Fish Eagle
Explicit	Directly discussing uncertainty with students	“You sit with them and allow them to critically reflect on their practice and realise that it's okay to express some uncertainty. You know, like, again, you can't just tell them it's okay to be vulnerable, you just have to show them.” - Mipha “Highlighting it. But maybe not in that way. I think verbalising what they're doing. So it's more of a shadowing or an apprenticeship, sort of teaching and verbalising what they're doing and why. And then signposting students to it.” - African Fish Eagle
Stealth	Hiding the uncertainty as part of your teaching	“I think the danger with a lot of these non-technical things is that if you, if you label them as such, then it's like communication skills. If you go, Hey, guys, we're gonna do some communication skills training today, everyone's eyes glaze over, as if you do the same thing without calling it that.” - Peloton “I think we probably have to do it stealthily is actually my solution. Because I think when you're in it [medical school], and I remember being in it , you know, I just want knowledge. You are just absolutely desperate for knowledge.” - Turnip
Category	**Description**	Illustrative examples

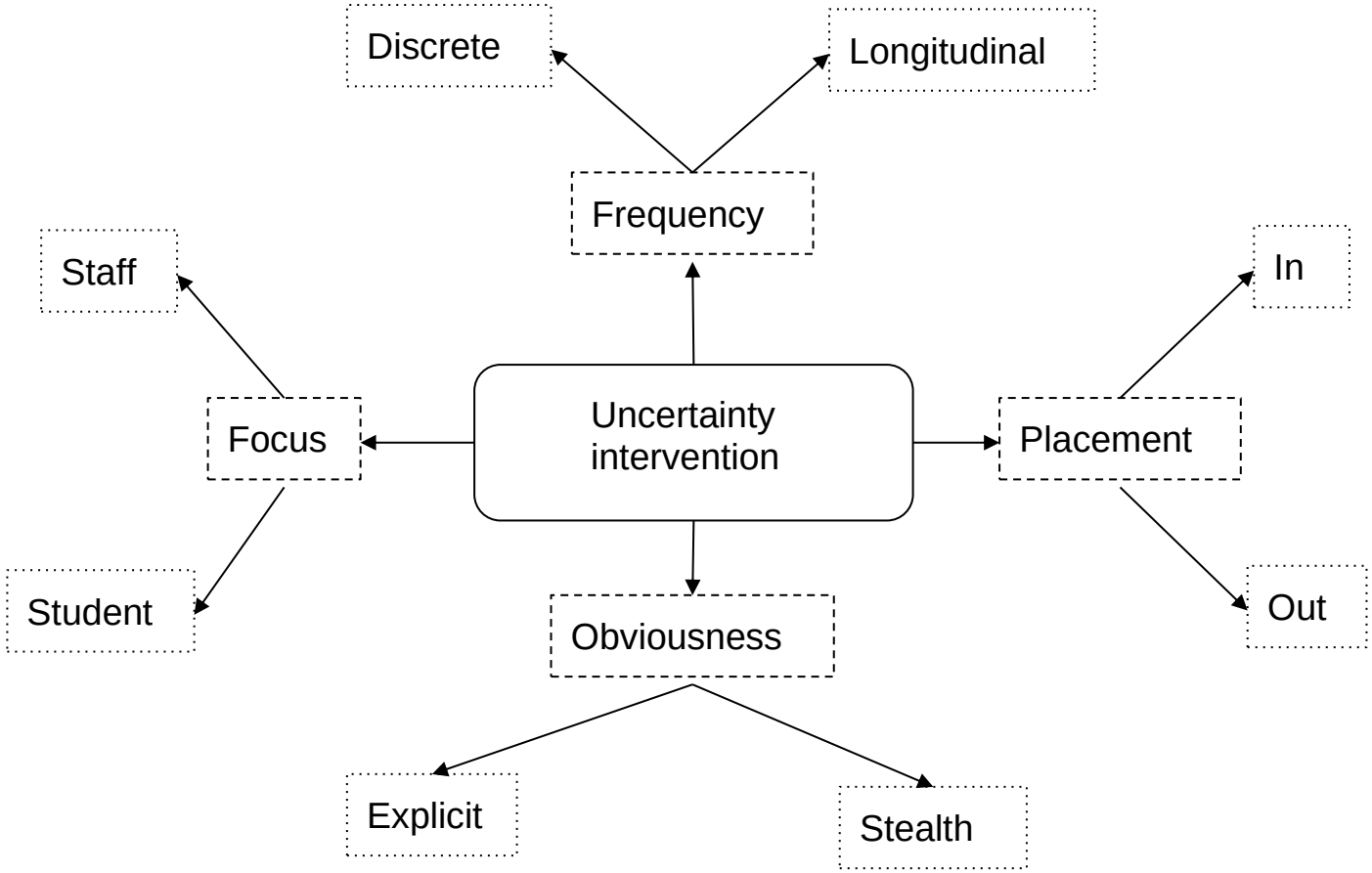


Figure 4.3 - Outcome space related to considerations needed when creating an intervention concerning uncertainty (arrows relate to choices, dash boxes are categories and dot boxes are sub-categories

4.3 Discussion

4.3.1 How did educators conceptualise uncertainty?

When the participants discussed their conceptualisation of uncertainty, they were free to describe their uncertainty. Rather than being able to concisely define it, I found that many instead listed the causes of uncertainty, including the emotions they associated with it. They also discussed uncertainty in the context of certainty as well as its inherent and ubiquitous nature. The lack of a concise or consistent way to define uncertainty would continue to suggest that there is no single unifying definition for the phenomenon, which has already been described in the literature (Bhise et al. 2018).

I found that the category of the expectations of others being a source of uncertainty, one that was frequently repeated by the educators, has yet to be discussed in the literature. This finding implies that uncertainty relates to how well the educator knows the person with the expectations. It could also imply that the majority of work for a doctor is to meet the expectations of others rather than by some predefined result (such as treating a symptom or curing a pathology). This is perhaps why medical students on General Practice placements are encouraged to ask about a patient's expectations, as knowing and meeting these expectations reduces the uncertainty for the student and improves patient satisfaction (Freilich et al. 2019). In addition to the examples I gave in the outcome space I am including a longer extract which describes the pressure to arrive at certainty. Max, in this passage, does not struggle with uncertainty, but feels that others do and they have expectations that Max should not be uncertain. From interview 6 with Max during their time in paediatric A and E:

> *"I can remember trying to, like, chat that over with the nursing staff sometimes, and, you know, not really sure [what the diagnosis is] this is a bit*

in between. And it really didn't go down well, you know, this sort of uncertainty. And, you know, because they [the nurses] just wanted decisions, and they would have rather… and actually you sort of learn this as a strategy, you know, as you as you go on in your practice that, you know, even if you feel uncertain, inside, you know, there are times when it can make your life easier just to present the veneer of certainty. And just say, okay, is it, you know, so this is what we're going to do. And we would have done a lot of, you know, nonsense things for those babies like, so we would have went, like, taken bloods or whatever. And the blood tests very often didn't contribute much useful clinical information. But what they did do was, you know, they, they kept your colleagues happy, you know, because you were doing something, they bought you a bit of time, maybe just to kind of reflect on your, on your own decision making, I guess." - Max

This passage is reminiscent of Actor-Network Theory (Fenwick and Edwards 2010). In this social theory, the world is considered to exist in a fluid network of relationships. For this example, the doctor and who they are interacting with are in a fluid relationship, and their interaction is not in isolation but instead a network. The doctor cannot fully appreciate what prior interactions the patient has had, or is expecting from the consultation. This can cause uncertainty for both the actors. The patient will have certain expectations based on previous interactions in a health care setting, including reasons they are currently seeking help and the journey that has led them to this interaction. Understanding and managing expectations is an important requirement in becoming a doctor, and being uncertain of what these expectations are can complicate proceedings (El-Haddad, Hegazi, and Hu 2020). For doctors managing patients, patient interactions are often followed by interactions with other healthcare providers and an anticipation of their individual needs. This will often be about making decisions when uncertain because these are the expectations that others have. Learning how to manage the fluid network of relationships, as Max described above, is a key part to managing this expectational uncertainty. This form of uncertainty has already been classified in the academic literature as uncertainty due to complexity (Han, Klein, and Arora 2011). Managing

expectational uncertainty is about understanding that there is no single solution to a problem and meeting the expectations of others are often more important than fulfilling any clinical curiosity (Freilich et al. 2019).

The emotional state caused by uncertainty, was a reoccurring category as well as a concept described in the literature. There were the negative emotions, such as anxiety and burnout, which had previously been identified in the literature, but there were also many positive emotions such as excitement (Cooke, Doust, and Steele 2013; Grupe and Nitschke 2013). These positive attributes reinforced the view that uncertainty was not in fact always problematic and should indeed be embraced. Many educators used the related concept of certainty to describe an area that was problematic. From various interviews:

> *"I think if someone said that they, you know, we're certain a lot of the time. I don't know that... That rings alarm bells, that's nearly a red flag. 'I'm certain that's the answer.' Are you though? Or are you just telling yourself that because it feels a bit more confident?"* - Samuel

> *"Like, you thought there was no hip fracture, there was a hip fracture, you didn't maintain that uncertainty of could there be a hip fracture? You know, kind of thing? That's like, one of the worst things you can do, isn't it? And so, yeah, there's lots of stuff in medicine about, especially if you go into diagnostics and diagnostic reasoning around how do you keep your uncertainty, the negative capability thing… how do you keep people from jumping to a diagnosis and then you get all your confirmation bias and all those problems?"* - Mipha

She also summarised this more concisely:

> *"The more certain position is the more dangerous one."* - Mipha

Inherent uncertainty was an accepted part of the job, whilst inappropriate certainty was considered to be extremely problematic. One, uncertainty, allowed for more exploration and curiosity, whilst the other, certainty, might cause the physician to dismiss a correct diagnosis or follow the wrong treatment plan. The pressure to arrive at certainty is just one of the expectations placed upon a doctor. How to express uncertainty to others is a required skill of an experienced physician. Teaching medical students how not to arrive prematurely at certainty, despite external pressures, therefore appears to be a missing theme from the literature when teaching students about how to manage uncertainty. As eloquently put by Brené Brown:

> Choosing to be curious is choosing to be vulnerable because it requires us to surrender to uncertainty. It wasn't always a choice; we were born curious. But over time, we learn that curiosity, like vulnerability, can lead to hurt. As a result, we turn to self-protecting—choosing certainty over curiosity, armor over vulnerability, and knowing over learning. — Brené Brown (2021)

This idea of choosing to actively maintain uncertainty and therefore not to be surprised if the outcome was not what was expected seemed an important concept when teaching students how to manage their uncertainty. There is a fine line between this and being overly accepting of uncertainty, which can lead to an unwillingness to learn from patient encounters or follow up patients with uncertain diagnoses (Hancock and Mattick 2012). The difference is between maintenance and acceptance, with the former being aimed at increasing curiosity and the latter at reducing it. This is all in contrast to how medical students are summatively examined, where students are rewarded for certainty in both written and oral examination formats. Altogether this suggests that there is perhaps a mixed message taught to medical students when confronting uncertainty and why some students might find the concept troubling (from interview 7 with Robbin Collinson):

> *"But I don't think we're good at saying to medical students, 'Actually, you need that flexibility.' And I guess they don't get it either. Because they have*

their OSCEs [Objective structured clinical examination]*, and they just want to say the right answer."* - Robbin Collinson

The issue of students not being prepared for uncertainty because they too easily accept certainty might be rooted even deeper than in medical training. For example, students are overly rewarded by expressing certainty. Medical school placement acceptance follows a specific style of cognitive testing, normally scientific exams, through mainly written answers and also verbally at interview (Barr 2010). Samuel described the expectation for certainty with medical students (from interview 11):

"And that's part of it is, we just expect people to be nearly 100% certain all the time. I know what I'm doing. I know what I'm doing with my life. I know what I'm doing with this patient. I've got a plan, what's your plan? And actually, that's just absolutely bollocks." - Samuel

From school science and undergraduate examinations with correct answers to commitment to speciality requirements, students are continually rewarded for being certain, while educators suggested that this was problematic. Below is a quote on the matter accredited to Mark Twain:

"What gets us into trouble is not what we don't know. It's what we know for sure that just ain't so." - probably Mark Twain (quoteinvestigator.com 2018)

Perhaps, as suggested by some, adequate tolerance to uncertainty should also be an entry requirement to medical school (Simpkin and Schwartzstein 2016b).

Uncertainty was conceived in a broad variety of ways. Ideas expressed in the literature were repeated by educators who had faced the phenomenon first-hand. The generally accepted varieties of uncertainty described by Han et al. (complexity, ambiguity or probability), were encountered during my research along with other concepts such as expectational uncertainties and problematic certainty. My findings reiterate that there are a number of different uncertainties faced; that these are

largely inherent and can be seen as a positive part of clinical practice and that every person has their own unique understanding and relationship with uncertainty.

4.3.2 How did the educators feel they learned to tolerate the uncertainty they faced or how do they currently manage uncertainty?

How educators felt they learned to manage their uncertainty, and how they currently manage uncertainty were areas that had not been explored in the literature. The questions were answered in both literal and hypothetical ways, as it was often difficult for the educators to remember how they crossed the threshold of being able to manage uncertainty.

The *self* category described individuals who had learned to manage uncertainty alone. This was through anticipation of possible outcomes, acting confidently until they achieved appropriate certainty or through reflection on actions. For the educators who discussed reflection, respondents tended to think of an unsatisfactory response they had made when faced with uncertainty and reflect on what they would do differently if they had the opportunity now. One educator discussed that she tried to do this even if things had gone satisfactorily, to try and always improve her practice. This method of self-improvement is similar to that of Kolb's reflective learning spiral, where the educator would experience uncertainty, reflect on this and then act differently when they experienced similar uncertainty again (Kolb and Kolb 2018).

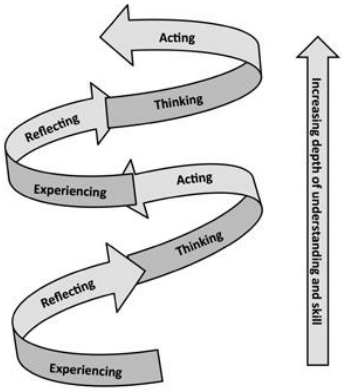


Figure 4.4 - Kolb's learning spiral (Kolb and Kolb 2018)

Educators who learned how to manage uncertainty from others, described the apprenticeship model of medical learning, where students first start with observation then gradually become more involved with clinical practice (Gheasuddin, Misra, and Patel 2021). Some also described creating a psychologically safe working environment, where actions were never punished. Punishing individuals for errors greatly impacts on patient safety as this encourages individuals not to report any errors made (Rogers et al. 2017; Radhakrishna 2015). Creating a culture where departments can all learn from the errors of an individual allows for both that individual and those in the department to grow.

Teaching students in the environment they will be working in is very much in line with various behaviourist theories of learning such as social learning theory or situated learning theory (Horsburgh and Ippolito 2018; Badyal and Singh 2017; Lave and Wenger 1991). In social learning theory, students learn by observation and imitation of others, as well as by observing the outcomes of the actions, considered as rewards (positive reinforcement) or punishments (negative reinforcement). According to this theory, rewarded behaviours are more likely to persist and punished behaviours are less likely to. Integrating this into observations of others when managing uncertainty, involves correctly interpreting patient satisfaction via their responses, both verbal and non-verbal. Situated learning theory expands on social learning theory to suggest that the apprenticeship starts with observation and

then becomes legitimate peripheral participation, allowing the learner to integrate into the community of practice (Lave and Wenger 1991).

All the educators ascribed learning how to manage uncertainty to time or experience. This was an unhelpful response when considering specific recommendations for future uncertainty teaching. This response was probably so common as they had learned to manage uncertainty via the hidden curriculum of medicine, which is an important yet intangible area to try to modify for a medical curriculum. (from interview 7 with Robbin Collinson):

> *"I personally think it is better to get that clinical exposure in early because a lot of our learning is so hidden. It's not in the curriculum, per se. It's about observing what others are doing and what do you pick up on how you figure things work."* - Robbin Collinson

This quote and the hidden curriculum, speaks of the amount of experience and time necessary to be able to learn the skills required to be a doctor and how skills differ from factual learning (Yazdani, Andarvazh, and Afshar 2020). The passage also alludes to the gestalt nature of medical training and that the designed curriculum cannot cover the full range of skills that are required and that some skills need to be absorbed with enough time in an appropriate environment (Cook 2009). The apprenticeship model of medicine, and what Robbin Collinson is speaking of (hidden learning through observation), likely equips learners with a variety of different problem solving skills, which are used when managing uncertainty and can only be acquired through an appropriate amount of time and relevant experiences.

The final data I included for this response concerned an educator who felt that managing uncertainty, even for a very experienced practitioner, was not always possible and that other factors needed to be met before they could arrive at a response. This educator equated their mental capacity to the working memory of a computer, and how some of this capacity would be used by other requirements of living. This nuance, adding situational conditions to the ability to manage uncertain

situations, was an important observation. Both cognitive load theory and Maslow's hierarchy of needs are relevant here (Hale et al. 2019; van Merriënboer and Sweller 2010). Cognitive load theory suggests that an individual can only function optimally when they do not feel overwhelmed by other constraints. In this example, the educator could manage their uncertainty when their other needs were suitably met and there was not too much other uncertainty in their life. Maslow's hierarchy of needs goes further and suggests that there are basic needs, water, rest, safety and so on, that need to be met before higher needs and functions can be performed, such as managing uncertainty (Figure 4.5).

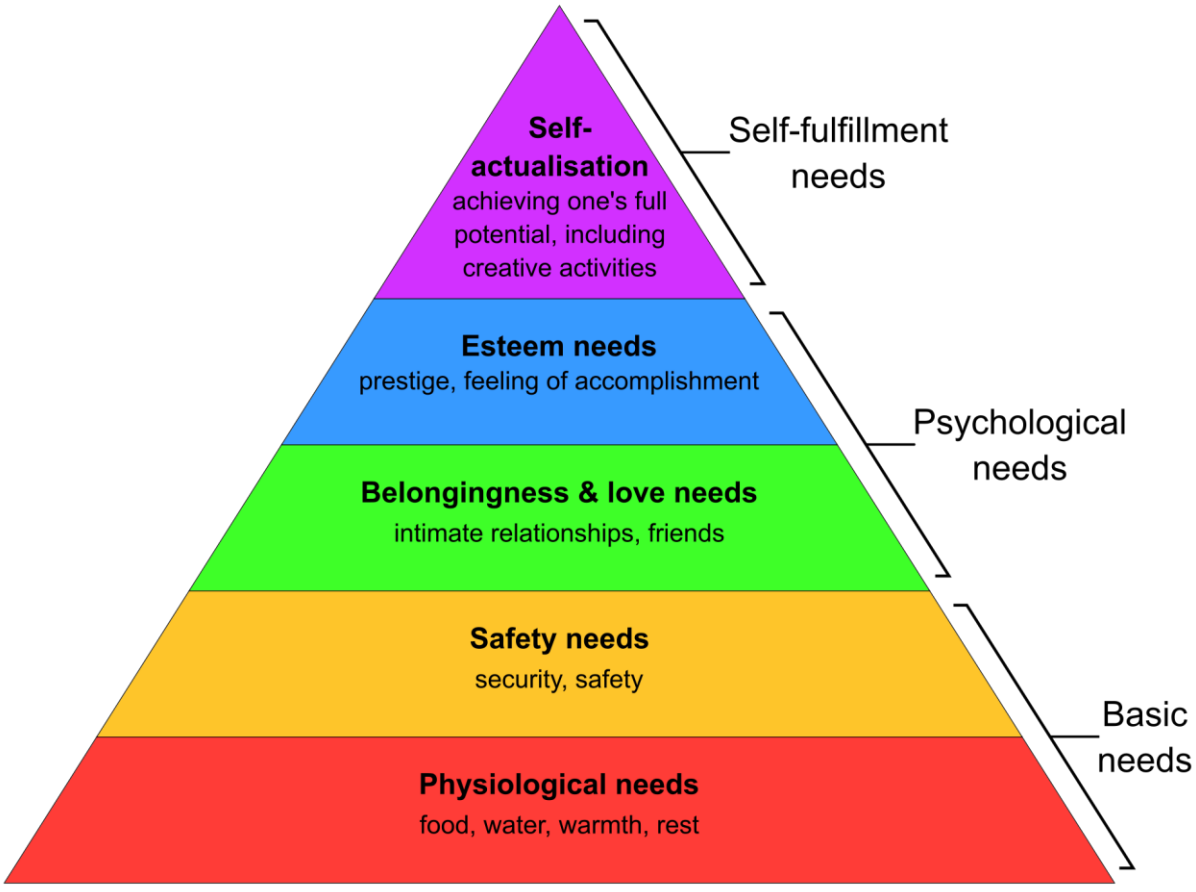


Figure 4.5 - Maslow's hierarchy of needs - Image adapted from Mcleod (2018)

Of note, no educator mentioned their training at medical school when considering how they learned to manage uncertainty. One even remarked on this (from interview 10 with Starfox):

> *"Nobody in my medical school ever sat down and said, "Now we're going to talk about uncertainty."* - Starfox

This would suggest that, for these educators, the threshold of how to manage uncertainty was only conceived following graduation, or that many of the lessons that were learned about how to manage their uncertainty were indeed hidden. For these educators, learning to manage uncertainty was likely a complex, individual and gradual process.

Reflection, observation of others and time and or experience played an important role in learning this complex skill. A number of learning theories had been described by educators either formally or informally during this discussion. Variation theory describes learning as an 'expansion of awareness' for the learner and suggests that all learners learn differently (Åkerlind 2015). Ideally, differences between learners should be anticipated and variation in teaching should be incorporated into curriculum design (Åkerlind 2015; Bussey, Orgill, and Crippen 2013). This was reflected by the educators, as even experienced learners failed to have much in common when saying how they learned to manage their uncertainty other than the vague notion of time and experience.

4.3.3 When do students experience uncertainty?

For the educators who chose to answer the questions concerning when students experienced uncertainty there was a clear divide between those approaching the question from the side of the course organisers and those imagining what the students were going through. This divide was also expressed when describing the type of uncertainty, with some contemplating individual uncertainty and how a student might cope with that ('Should **I** be at medical school?') and those discussing the inherent nature of uncertainty in medicine ('How to teach *grey* areas?'). A good example of this individual uncertainty was described by Wilko in interview 9:

"So for medical students, I think it's uncertainty about whether they are deserving of their place in medical school. Uncertainty, whether they'll make the grade… uncertainty about whether they really want to be a doctor at all, and uncertainty about their knowledge and understanding." - Wilko

For these answers, there was also a separation between tangible uncertainties, where the reason for the uncertainty was clear, and intangible uncertainties, where the source of uncertainty was more general, or at least harder to identify and classify. For the tangible uncertainties, this was often related to students shadowing doctors and experiencing what all doctors experience when making a clinical decision, or just experiencing unexpected uncertainty or being unable to locate the source or type of uncertainty. Below are two accounts that offer insight into a student's individual uncertainty. The first was related to the educator's experiences of when they felt uncertain as a student and they struggled to locate the source (from interview 5 with Mipha) and the second, from a different interview, suggested reasons why this might be the case (from interview 3 with Peloton):

"When I was in Cuba, doing my elective, I didn't speak brilliant Spanish. So the patient would talk to me and I'd be like... and I was doing geriatrics... The patient talk to me and I'd be like, 'Am I not understanding you? Because my Spanish is rubbish? It's me? Or are you actually talking nonsense, because you've got dementia?' You know, like, you couldn't locate where the uncertainty is." - Mipha

"I think that there's this sort of general point isn't there about not knowing. Not knowing things because you don't know. Or not knowing things because nobody knows. And I think when you're learning, you don't really know which of those categories your ignorance or uncertainty falls into? This is a big morass of not knowing." - Peloton

What Peloton is describing is the problems that students have with epistemic uncertainty. Others found these uncertainties both necessary and formative;

equipping future doctors with the skills (and confidence) they would need and almost encouraging students to answer confidently when uncertain, as this is what is expected for exams (from interview 11 with Samuel and interview 5 with Mipha):

> Jonathan Sadler: *"When do you think medical students experience uncertainty?"*
>
> Samuel: *"I mean, again, I would, I would suggest all the time. And I think part of medical school training is teaching you to hide it. And teaching you to 'fake it till you make it' and teaching you to, you know, play the heuristic game and just learn how the system works, and, and blag and bluff and bluster. And, you know, medical students will tell you that they 100% lie when they tell you they can hear the apex beat, but they say the right words and put the stethoscope in the right place. And, and we let it slide."*
>
> *"I remember for finals… 'Just learn what is in grey book' [a collection of notes made by junior doctors similar to the Oxford Handbook of Clinical Medicine[22]]. That was the advice given to us like, learn grey book, you'll be fine with all the management stuff. You know, that's what you need to know. Yeah, like you [are] blagging experience is because it's written by people with all that experience. And with all that levels of uncertainty, etc. So how do you blag that? Well, you just repeat grey book as though you thought of it, and then everyone thinks you're clever. You know. Yeah, it's all about the blag."* - Mipha

As expressed by some of the participants, the educators themselves were probably not in the ideal situation to answer these questions, as they themselves were at least a few years away from medical student life. I noted that the overall enthusiasm for this question was lower than for the rest of the interview, with some reluctance to answer the hypothetical questions. The next chapter covers my discussions with students on when and how they experience uncertainty (Section 5.2.2).

[22] (Murray Longmore et al. 2010)

4.3.4 Should uncertainty be taught to students?

The educators' responses to this question demonstrated significant variation and beliefs concerning what uncertainty was and how appropriate teaching students about uncertainty would be. Along with clear responses were a collection of conditional responses. The inclusion of 'when students have the right experience' in the 'Yes but' category highlighted how difficult it might be to try to place such an intervention and included a pragmatic element to the placement of such teaching. Jolene in interview 2, expressed the dangers of trying to teach students about uncertainty before they have had a chance to experience it.

> *"But with regards to like formal stuff, the reason why I'm hesitant is because of my experience, is because it's such a like… it's conceptual. So it's very hard to just hear someone talking about it and understand what that feels like."* - Jolene

'The right experience' of clinical uncertainty itself is a complex concept, and will be different for every medical student and medical school, each of which will have varying approaches to the start of clinical training and exposure. Some educators suggested that the student would have experienced some medical uncertainty and tried to manage this uncertainty whilst on clinical placements. Some educators went as far as acknowledging that there were differences between medical schools (from interview 7 with Robbin Collinson):

> *"I think it [uncertainty] should be throughout the curriculum. The problem is obviously, different schools are modelled differently."* - Robbin Collinson

These educators were describing that learning how to master a phenomenon such as uncertainty required students to have 'the right experience'. This idea is reminiscent of Lave and Wenger's legitimate peripheral participation model of learning as part of their situated learning theory (Lave and Wenger 1991). Here

students gradually engage, in a safe manner, with a problem until they eventually become masters of this problem, taking a bigger role on each sequential exposure. For example, students could be exposed to clinical uncertainty when shadowing a junior doctor who demonstrates how they would manage the situation when uncertain. Then the student themself is called upon to demonstrate what they would do when uncertain.

Educators suggested why some students would likely not be interested in the concept, making any teaching about it challenging, with students prioritising learning that would improve their exam results over their clinical functionality (from interview 7 with Robbin Collinson):

> *"They don't want to hear it. I think in preclinical, all you want to know is what do I need to know to pass for my exams, which doesn't change. But I think it's only when you start with clinical exposure, you go 'Actually, I'm not quite sure if that sounds good or not.'"* - Robbin Collinson

This educator suggested that students needed to be in a position where managing their reactions in a clinical environment became a greater priority than passing their formative exams. This would be different for every student with some students viewing this only as being relevant following graduation, however, the educator suggested that this probably began when the student started on clinical placements. The students needed to have approached the threshold of uncertainty in medicine before they can recognise it and understand why it is problematic. Following this, they can then learn about how to manage it.

Not all educators believed that teaching students how to manage uncertainty was necessary or indeed possible. Some felt quite strongly that this phenomenon could not simply be taught to medical students in any way that would be meaningful. This idea, that introducing new learning objectives to try and teach students about uncertainty would be self-defeating, has been suggested before by Barnett (2012).

The phenomenographic methodology was helpful for this question as I used it to find variation in possible responses through purposive sampling. The analysis clearly displayed the contrast and division in people's opinions towards this area. Different educators had different beliefs and rationales for why they thought uncertainty should be taught to students and when would be a good time to do this or why this might not be the case. Other pragmatic considerations had to be explored before I could consider what recommendations to make, however, there was certainly much demand and belief from some in medical education that medical students should be taught about uncertainty.

4.3.5 Have you ever tried to teach the concept of uncertainty to medical students?

There were many different examples given by the educators as to how they had tried to teach medical students about uncertainty. These included long-running programs, such as Clinical Debrief which was described by the educator as running for over ten years, to off-the-cuff opportunistic teaching such as Frequency Gambling. Similar methods to Clinical Debrief have long been used to teach GPs in training how to manage their uncertainty (Danczak, Lea, and Murphy 2016). As for Frequency Gambling, this method could be considered archetypal of Dewey's experiential educational style, where teaching is physical, pragmatic, relevant and of course, experiential (Fins, Bacchetta, and Miller 1997; Yardley, Teunissen, and Dornan 2012). The educator, who described the branching possibilities that might occur in the situation, was also describing how to manage aleatoric uncertainty, where the outcomes are all known.

There were clear similarities between the simulations described by one particular educator and their approach to uncertainty and a published uncertainty simulation (where there was no diagnosis)(Scott et al. 2020). The educator described what

happened if students were exposed to this novel version of uncertainty too early in their medical education journey (from interview 8 with Plato):

> *"Right, let's have a history-taking session where we don't know what's wrong with the patient. Let's just make up some random symptoms. The actor will be given random symptoms' And I think it was vaguely sort of gynaecological thing. And then it was really interesting that at the end of it, the students said, 'Okay, well, what's the diagnosis?' And I said, 'Well, we don't know.' and they absolutely freaked … 'That's medicine. Sometimes you don't know, the patient leaves and you got no idea. That's....' and, you know, they found that you know, by that time, they were quite happy facing anaphylaxis and odd history and patients getting irate, but not knowing absolutely freaked them out."* - Plato

In spite of there being no formal recommendations in the curricula of the educators, many of the educators still had tried to teach students how to manage the uncertainty of related topics, even if their methods had all been radically different from each other. It is unclear how successful any of the methods described were. This would suggest, as was apparent in the literature (Chapter 2), that there is no single way to teach this subject and that uncertainty can be taught in both formal and informal ways, both explicitly and implicitly.

4.3.6 Where does uncertainty in medicine fit in a medical school?

The answers to the question of when to teach students about uncertainty depended on how educators viewed the areas discussed in earlier questions. Nevertheless, all educators had an opinion on the placement of a possible intervention. I felt that this question left educators pondering and answering with less certainty than in previous questions. This was perhaps because each medical school is so different and also because the educators themselves had strong opinions about the nature of medical schools and what could or should be taught. This generated a relatively simplistic

outcome space with categories arranged in a hierarchy loosely based on the stage of the intervention, beginning with *Throughout* their medical journey and ending with *Graduates*.

Teaching about uncertainty throughout, but especially from the start of undergraduate medical training, was similar to interventions that I discovered during my literature search, which mainly concerned teaching uncertainty to first year/preclinical medical students (Bentwich and Gilbey 2017; Liou et al. 2019; Fernandez et al. 2016). The category of *Throughout* could be controversial in itself, especially for those who believed that this was a strictly postgraduate area. For these educators who thought that teaching should be throughout medical school, they were suggesting that the medical school curriculum should be completely redesigned or reimagined with the active inclusion of management of uncertainty integrated throughout the course, or the addition of uncertainty in all current modules. The practicalities of these responses were discussed further in later questions.

The category *Having Experienced Uncertainty* is complex, especially since many educators believe that students experience uncertainty all the time. Separating out uncertainty experienced during clinical medicine, or experiencing the inherent nature of uncertainty in medicine from general or individual uncertainty, probably would have added clarity to what educators were discussing. There was also the possibility that students might not be aware or even exposed to the uncertainty faced by doctors, especially with some doctors shielding their students from this. This would perhaps mean that students would not be aware of how inherent uncertainty was to medicine. This concept was described by Jolene in interview 2:

> *"And it would be particularly nice to see some of the specialties that maybe appear very confident with their decisions all the time, to show their uncertainty. Like not just, it shouldn't just be like when you're on your medical rotation we'll learn about uncertainty. It should be clear [to students] that surgeons feel uncertainty [too]."* - Jolene

The category *Having Experienced Uncertainty* is also highly conceptual and individual to both the students and the educators expressing these opinions. It was similar to the category of *Yes but* from the earlier outcome space concerning if students should be taught about uncertainty. It is unclear how helpful this category could be when determining where, or if, any possible intervention should be placed should one be required. Educators were suggesting that teaching about uncertainty should be left to a time when students were mature enough to comprehend the concept, which, for the majority of students, would not be the start of their course and instead be once they have started full-time clinical medicine. This area would be highly individual but more dependent on the course structure rather than on the students themselves, as some courses expose students to clinical settings in their first week, whilst others have a more gradual exposure.

The *Graduates* category responses also required some further analysis. This was the response of educators who believed that students need some semblance of certainty, or knowledge before they could approach appropriate management of uncertainty. Too readily accepting inherent uncertainty, and therefore being unwilling to learn from it, has been seen as problematic elsewhere in the academic literature (Hancock and Mattick 2012). Delaying uncertainty teaching until after graduation was a concept repeated by many of the educators, with the suggestion that any teaching before graduation would at best be poorly received and at worst be futile (from interview 3 with Peloton):

> *"What you want from an expert is someone who's able to manage complex and ill-formed problems. But you, you can't really manage those until you've learned to manage the straightforward, easily recognisable ones. And it's, it's a bit unfair presenting the fact that difficult things exist. To expect those who haven't quite formed their skills and identities as well."* - Peloton

This conception, understanding the limits of expected knowledge, was discussed many times by different educators in different contexts, including how they themselves struggled to overcome uncertainty. The conception ultimately describes

the transition that doctors have between experiencing epistemic uncertainty, where the possible outcomes are boundless, to aleatoric uncertainty, where the possible outcomes are known. This might even be an identifiable threshold that is crossed when learning how to manage uncertainty. Along with these responses were a collection of responses about when would be a bad time to teach students about uncertainty. Here the concept of *not too early in training* was expressed, which could be seen as an allied statement to *having experienced uncertainty*.

Throughout the interviews, the educators frequently expressed the idea that students were almost unwilling to learn certain skills that they did not directly see as being beneficial to their current situation such as an upcoming assessment. This concept, students not wanting to learn about uncertainty, is addressed further in the following section concerning how *obvious* to make teaching.

Where any medical school places an intervention, should this be something they see as necessary for their student outcomes, will depend on both what style of curriculum they represent, the values of the medical institution and what the intervention might entail. However, there are certainly arguments both for and against placing interventions at various points throughout the curriculum. This has been reflected in the recommendations (Section 4.4).

4.3.7 How would you teach medical students about uncertainty?

The placement and the type of intervention required to teach about uncertainty were related topics. The phenomenographic methodology allowed me to highlight the vast array of differing opinions about how this complex subject area could be taught (Table 4.13). While some felt that more traditional methods would work well, others disagreed (from interview 6 with Max):

> *"I don't think more lectures on that would be helpful."* - Max

The choice of a pedagogical methodology for learning something so complex and individual would need to be considered by anyone planning an intervention. Experiential learning such as situated learning and legitimate peripheral participation were suggested by some of the educators over more traditional methods, although many of the educators were speaking hypothetically and therefore may not have considered the practicalities of what they were discussing (Lave and Wenger 1991; Yardley, Teunissen, and Dornan 2012).

The importance of hiding or integrating teaching into other traditional topics was a common response to the question. Educators suggested that students might be resistant to an area they have yet to fully appreciate. One educator suggested a way uncertainty could be incorporated into clinical teaching was by selecting a symptom from a patient and exploring how to consider the uncertainty involved for this symptom (from interview 9 with Wilko).

> *"If you're teaching about a case in say a cardiopulmonary module, and you're focusing on a symptom, such as breathlessness, you could use a case vignette to demonstrate to the students a clinical reasoning approach. You know, if you've got somebody breathless, you need to look at the demographic of that patient"* - Wilko

Another educator suggested that a more casual approach to teaching about uncertainty should be taken, by making sure all educators discussed the grey areas of medicine as this included those with uncertainty (from interview 3 with Peloton).

> "*I think that's the best place to embed it so rather than having an uncertainty module, you'd have something that was almost by stealth. And every time they talk about something a bit unusual, then it's touched on and it becomes just a natural part of what happens."* - Peloton

There was a clear divide between those who thought the focus should be on educating staff to express the uncertainty they faced when managing uncertainty clinically in front of students, and those who focused more on what the students experienced, or aspects that they could more easily control, such as lectures or simulations. There is an argument, especially seeing that most people learned to manage their uncertainty very differently, that multiple approaches should indeed be taken. Variation theory - anticipating that students will learn the subject differently and that this can and should be supported - was yet again relevant when considering how to approach an intervention (Åkerlind 2015). Considering all the data, there is clearly no single way to teach about uncertainty and multiple methods need to be used until eventually, the student has crossed the threshold from being overwhelmed by uncertainty to being able to manage it. This diverse range of solutions demonstrated yet again that being able to manage uncertainty was indeed a threshold concept, and that crossing this threshold would be, like with all threshold concepts, troublesome, as described by Mipha in interview 5:

> *"So people talk about that [managing uncertainty] in terms of threshold concepts... you get into a threshold, and then you help them leap over that threshold. But there's always this uncomfortable bit where they're before the threshold going, like, No, no, no, I refuse to believe that. That cannot be so."* - Mipha

This difficulty was of course not expressed by all and there were the optimistic educators who felt that this area was simple and that there were solutions already in place that could be called upon such as the Clinical Reasoning in Medical Education group (CReME)[23] ("News and Events" 2021). Example from interview 9 with Wilko and 10 with Starfox.

> *"I don't think it's that difficult. And I... well, she says that... there is a clinical reasoning medical education group. I think the acronym is CReME."* - Wilko

[23] CReME aim to provide resources that can be used to improve clinical reasoning.

> *"I don't think it needs lots of money and lots of resources. It needs a bit of time."* - Starfox

There are clearly a number of different methods to teach students about uncertainty, all depending on your viewpoint towards what needs to be taught and how it could be taught. This has already been demonstrated in the literature (Patel et al. 2022; Moffett et al. 2021).

Finally, there were also themes that did not fit within the hierarchy of the outcome space, often when educators felt they were not able to fully answer the question. Samuel in interview 11 suggested that they did not fully understand the problem and was therefore unwilling to give a detailed response:

> *"So I think my first step [in designing teaching] would probably be to do a much, much bigger version of your PhD, and really speak to as many people as possible. So that I could understand how people perceive, conceptualise, and understand what uncertainty is, because it's only really then when you understand it, and have explored it in that way, can you start to build some way of addressing it."* - Samuel

This of course was the goal of this research, and it is promising to see that some educators want to ground their suggestions in research. Hopefully, the conclusions of this work will help justify how people teach students about uncertainty.

This discussion has reviewed and analysed the findings of this research and how results might relate to current educational theories. The findings for each question were broad, which was the intention of the methodology, as the area of understanding and teaching uncertainty is still currently poorly developed. It is also unsurprising that a methodology that aims to uncover variation would discover many variations and that variation theory would be considered so relevant. Taking into

account the number of different ways uncertainty has been taught and could be taught, the recommendations I have arrived at have reflected this. Below I have generated some early recommendations based on this data, however, I was appreciative that there was still more data that needed to be collected and analysed before the recommendations could be finalised. The following section will discuss some of the recommendations based on my interpretation of the data.

4.4 Summary and recommendations

A large amount of data has been acquired and analysed and I will summarise it before making some recommendations. I will include the original research questions here, to demonstrate the structure behind the research.

1. What is meant by uncertainty and how is it currently taught in medicine?

- Uncertainty was inconsistently conceptualised, with every contributor having a different view or experience of the phenomenon. Managing uncertainty was an important skill to acquire as a junior doctor or earlier, however being overly certain was considered problematic.
- Very few educators felt that they had been directly taught how to manage their own uncertainty, but this had not been a barrier to learning how to manage it. Instead, learning how to manage uncertainty had come about with time and experience as well as individual reflection and support of others.
- In practice educators taught their students about how to manage uncertainty using primarily informal methods rather than it being some explicit curriculum topic.

2. What do medical educators and medical students think about uncertainty?

- There was universal agreement that uncertainty was inherent in medical decision-making and that this was normally conceived as aleatoric uncertainty. Managing this uncertainty was an important skill to acquire as a junior doctor or

possibly earlier. The ability to manage uncertainty was considered to be a malleable individual property.

- Students were thought to experience uncertainty all the time, not necessarily related to clinical medicine. This was assumed to be epistemic uncertainty.

3. What do these findings mean for uncertainty in medical education?

- Most educators thought that medical students should explicitly be taught the uncertainty they will face and be taught that such uncertainty is normal. Some thought this should only occur when it became relevant to students. However, some doubted that it could be done in a constructive manner.
- A wide range of topics and a variety of methods have been or could be used. These included both informal hidden methods and formal longitudinal methods targeting either the students or those working at the institution.
- Variation in methods was considered important because just as there is no one type of uncertainty and there is also no single way of teaching students about it.

As beliefs and problems around uncertainty appear to be so personal, more information is needed from student participants such as: How do students conceptualise uncertainty? Do students recognise the divide between inherent medical uncertainty and the generalised uncertainty they have as a student? Do students feel the need to be taught about uncertainty and if so how?

Based on the experiences that the interviewees shared with me, it is possible to make some observations. Any individual or team contemplating teaching medical uncertainty management should consider:

1. Whether teaching should be implicit (such as teaching about differential diagnosis or advanced communication strategies for medically unexplained symptoms) or explicit (such as openly teaching about inherent uncertainty or discussing how individuals might feel in new environments).

2. Whether to modify current teaching (such as adding slides to lectures), or to add a bespoke intervention.

3. How much clinical exposure the students will have had, as this can determine the students' insight into medical uncertainty.

4. Whether to adopt a student approach (providing more resources for students) or a staff approach (asking clinical staff to be more explicit when uncertain to normalise this to students).

5. How to cater for differing student apprehensions of uncertainty as they progress along their medical journeys, for example, by adopting a longitudinal and varied approach to the topic.

In addition, whether or not they are teaching medical uncertainty management, medical educators should encourage students:

1. To recognise and express their uncertainty and develop techniques to productively manage rather than suppress it.

2. To engage with others (experienced practitioners or peers) and explore options when feeling uncertain.

This will allow them to appreciate that uncertainty is normal and to develop the skills required to solve unexpected problems.

These early recommendations started to lay the foundations of what I felt was needed when approaching how to teach students about uncertainty. The missing element, the experiences of current medical students, was required and added much-needed nuance and relevance to the data provided by the educators.

4.5 Concluding thoughts

The educators greatly added to the answering of the research questions even if they did not all agree with each other. Their insights into how they learned to manage their uncertainty and how or even if students should be taught about uncertainty, helped to create the conceptual frameworks around this research. In the next chapter, I followed up on these findings, filling in many of the gaps in knowledge or assumptions, by broadening the type of research participants by adding medical students. I have used these findings to update and expand on my research recommendations.

5 - Findings and Discussion - Medical Students

In this chapter, I review the data I collected following the focus group interviews with the medical students and discuss these new findings. Medical students conceptualised uncertainty very differently to medical educators, with some having little comprehension of clinical uncertainty and others acknowledging it but not suffering from it due to not having to make any impactful decisions yet. Uncertainty tended to be described as a personal phenomenon, about the abilities of the students or if medicine was the correct career choice for them. Medical students felt they experienced uncertainty when in a new situation or learning something new, during assessments and when contemplating their future. They felt that they learned to manage the uncertainty by having it normalised by their peers or through questioning those educating them. There was a strong desire for more teaching on uncertainty although with less confidence than the medical educators about what that would be. With this data, I have arrived at more specific recommendations.

5.1 Sampling and demographics

Twenty-nine students responded to the invitational email and were sent more information. Thirteen students signed the consent form and were invited to the focus groups. Two students did not show up to a focus group and I ended up with three focus groups in total. Two of the focus groups consisted of students from years four and five at BSMS. The last group had students in their first term at medical school. The information regarding the focus groups and year groups of the students, as well as the pseudonyms they selected for themselves can be found in Table 5.1.

Table 5.1 - Details for the focus groups

Focus group number	Pseudonym	Year group
1	Goku	4
1	T	4
1	Squirrel	5
1	Mbappe	5
1	Zeus	5
2	Francis	5
2	Danny	5
3	Jax	1
3	Emily	1
3	Charlie	1
3	Uma	1

5.2 Findings

As I wanted to witness variation, I collected data from opposite ends of the undergraduate medical training programme. I have displayed this data together in each outcome space. Due to the amount of time spent in focus groups (approximately four hours), compared with medical educators (approximately 12 hours), there were understandably fewer data and overall findings. The full transcripts are available in appendix F.

5.2.1 How did the medical students conceptualise uncertainty?

I began each focus group by posing questions about how the students conceived uncertainty. In turn, each student was able to discuss as much or as little on the topic

uninterrupted by me or anyone else. After all the students had answered the question, the students were given a further opportunity to openly speak on the subject, maybe reacting to something they had heard or expanding on their previous thoughts. As with the medical educators (Section 4.2), some sought clarification before expressing their thoughts:

Jonathan Sadler: "*What do you think of when you hear the word uncertainty?"*

Squirrel (year 5): "*So are we talking about medical fields only or uncertainty in general, because that's sort of uncertainty in life in general, and has got this sort of hint of adventure and excitement sometimes. Whereas in, in medicine, for me, sometimes it's synonymous with incompetence."*

I encouraged the students to describe what uncertainty meant to them and not have it defined by me. The students found this a difficult question often taking some time to think or re-phrase their responses. I created an outcome space with four categories that I created from the data (Table 5.2). They were: *actions, emotions, inherent* and *acceptance*. Reference quotes for each category can be found in the table below. From this data, I produced an inclusive hierarchy with earlier categories being encompassed by later ones.

Many of the students associated their experiences of uncertainty with *actions* that they needed to take or when faced with taking an action. They found themselves to be uncertain mainly in situations when they needed to make decisions and felt that they had inadequate information or were lacking support. They described a lack of experience in knowing the consequences of each possible action leading to an uncertain outcome.

The *emotions* felt when uncertain was another way that students described their comprehension of the phenomenon. Students described anxiety related to being uncertain or thinking that they should not be uncertain, along with the guilt of taking resources away from patients or being a burden to other members of hospital staff.

These were a few of the negative emotions that students described as being related to uncertainty. As for positive emotions, for some students the medical school was filled with uncertainties, but these were exciting as they felt they could bond from the shared experiences.

A number of the more senior students (from years 4 and 5) described discovering that uncertainty is an *inherent* part of medical practice. One student described realising that medicine was not as straightforward as they expected it to be, and that the teaching in the early years during lectures, was not adequate preparation for how much uncertainty they would encounter.

Some students felt that they had transcended the complications caused by uncertainty and learned to live with it. Their conceptions fell within the category of *acceptance*.

Each category expanded on the previous category and demonstrated different levels of sophistication concerning the phenomenon. However, some views did encourage some debate within the group. Here is an example from focus group 1:

> *"When I think about uncertainty, to me it equals, not knowing, equals being incompetent, equals my patients are not safe."* - Squirrel (year 5)
>
> *"I don't necessarily think uncertainty and incompetence are linked."* - Goku (year 4)

Table 5.2 - Outcome Space for the conceptualisation of uncertainty by students

Category	**Description**	Illustrative examples
Actions	Making actions and not knowing their consequences	"[Uncertainty is] Not being able to plan, not being able to predict what's going to happen, because it's all very uncertain." - Squirrel (year 5) "[I am uncertain when I] don't have much guidance, you can't really go to anyone else for any opinion, it's something that you're going to have to figure out yourself." - Danny (year 5)
Emotions	The emotions associated with uncertainty	"I think anxiety is a massive part. Anxiety and stress" - Charlie (year 1) "There are some times where I've been in the hospital and I felt guilty for being uncertain if that makes sense… A lot of medical students feel like a burden in the hospital. They feel like they don't know what to do there and they're just taking resources away from patients." - Francis (year 5) "It can be kind of exciting because I think it also helps that we know that we're going to be here for a while." - Emily (year 1)
Inherent	Recognition that uncertainty was a part of medical, and student life	"I thought it was all quite straightforward medicine. And how a patient comes in and then the GP can easily… or any doctor can say, 'Yeah, you've got this, we're going to do a test, do this, and this and this, and then we'll come to the answer.' But I think as I've progressed a little bit further, fourth and fifth year, I realised that more often than not, you don't know, you don't always know. And you always have to keep an open mind for that list of differentials." - Mbappe (year 5) "In relation to clinical medicine, uncertainty could be kind of like solving a puzzle. Like you never know, if you have the right answer for I don't know what a patient has, or if the patient presents to you in a certain way. But you try your best to gather all the information you can to try to reduce the amount of uncertainty I guess, for clinical outcomes, but there's always going to be that little bit of uncertainty that maybe from experience and from other things that you get on your path as a doctor, that kind of makes it easier. But it's always going to be there." - Francis (year 50
Acceptance	Understanding and accepting the nature of uncertainty	"That is just the nature of disease." - Goku (year 4) "So in summary, basically during my time at BSMS I feel quite okay with uncertainty." - Mbappe (year 5)
Category	**Description**	Illustrative examples

5.2.2 When do you experience uncertainty during training?

After I asked the students to describe what they understood by uncertainty, I then asked them to describe what was happening when they were experiencing the uncertainty (Table 5.3). A thorough exploration of this area was required as the suggestions that had been made by the medical educators were all hypothetical, and the data provided by the medical students could corroborate this or dismiss this. I found that the responses were very different depending on which year group was being asked, which is understandable as those in their first year had had only a minimal amount of time at medical school and therefore no substantial clinical exposure. From the data, I derived four categories. These were: *new skills and knowledge*, *placements*, *assessments* and *future*.

Some of the students described uncertainty when learning *new skills or knowledge*. One student described being uncertain when trying to reproduce what they had been shown to do, or just general uncertainty if they were approaching the skill correctly. The learning of new complex skills was allied to a doubt that the students would be able to retain all the skills and information obtained during the course. This self-doubt was not described by students in the final two year groups.

Many of the students described the uncertainty that arose when on clinical *placements*. This uncertainty was when trying to answer questions posed by those in teaching roles, and an overall lack of consistency from seniors, some punishing a lack of response and others encouraging it. One student felt that they did not experience uncertainty on placements as they did not have to make any decisions but anticipated that they would encounter this uncertainty in the future.

Assessments were another area where students experienced uncertainty. Both the format of the assessment as well as what knowledge was required and the outcome made them feel uncertain. There was a progression from unknown and uncertain in

year one, to then eventual acceptance, by those in years 4 and 5, that the fields of knowledge expected would be too broad to ever fully master.

The final category where the students experienced uncertainty was about the *future*. Many of those in the final two years of medical school expressed uncertainty concerning their future and if they were suited to a career in medicine after progressing so far down the medical path. Uncertainty related to knowledge and skills had dissipated, but had been replaced by starting to consider if life in medicine was for them.

The outcome space is presented with a chronological hierarchy where the uncertainties of the category are related to when the student would have experienced them during their time at the medical school.

Table 5.3 - Outcome space for when students experience uncertainty

Category	**Description**	Illustrative examples
New skills and knowledge	Acquiring new skills, or just having the ability to continually learn	"[I feel uncertain when] For example, history taking, and it's something completely new, and there's a whole structure to it." - Uma (year 1) "I guess there's uncertainty about building that capacity [to retain information]." - Jax (year 1)
Placement	Either directly experiencing or shadowing others having to make clinical decisions	"But I also think that some consultants push a bit of an iffy message about uncertainty, because sometimes when you get grilled about questions… if you don't know them, they make it seem as if you should know them." - Francis (year 5) "I think at the moment in medical school, you're quite it's okay to be uncertain, because obviously you've got, you've got your seniors and you've got whoever... whoever is supervising you, and it's quite a safe place to, to make your own decisions and management [as your senior will correct you if you are wrong]." - Mbappe (year 5)
Assessments	Uncertainty experienced prior to and during formal assessments	"I think the most recent example would be the KT [Knowledge Test]. For example, because it is the first time during an exam of that nature, first medical school exam, so there's a bit of uncertainty to know what to expect and how it's going to go." - Jax (year 1) "But I think another regular thing when I do experience uncertainty is definitely before any and all assessments. So it doesn't matter what it is. I can prepare for like, the entire year, I'm always going to feel like I don't know enough for it." - Goku (year 4)
Future	Uncertainty when considering the future	"I also like things like deciding where to go for F1. I've no idea." - Zeus (year 5) "Oh, it was the first time I've ever done a night shift a week ago. And it really took out of me and it also made me think about the future and whether I should be doing this?" - Mbappe (year 5) "And although you feel like you've got so much choice of all the different specialities, there's not really that much flexibility or that much encouragement to look kind of sideways and think a little bit out of the box." - Danny (year 5)
Category	**Description**	Illustrative examples

5.2.3 When do doctors experience uncertainty and how do they manage this?

Following on from the students describing when they experienced uncertainty, I asked the students some hypothetical questions about when they felt doctors experienced uncertainty, along with questions about how they felt doctors managed this. This was all done in the context of what they thought clinical uncertainty was. I generated two outcome spaces from categories derived from the data. The first outcome space concerned when doctors experience uncertainty (Table 5.4) and the second is about how they thought doctors managed this uncertainty (Table 5.5).

I felt that the medical students were not entirely confident about when doctors experienced uncertainty and were quite hesitant with their responses. However, the data from this question still led to the derivation of three categories; *unexplained symptoms*, *ethical and legal dilemmas* and *help*.

Being unable to explain the cause of symptoms was the first category I derived. The category included ideas that not all symptoms could be explained and this could cause uncertainty about how to act for both the doctor and the patient. How this diagnostic uncertainty was communicated with the patient was another conception within the category.

The *ethical and legal dilemmas* faced by doctors was another category derived from the data. One student described that doctors must be uncertain when having to act against their own moral code, or if there were legal consequences to the actions of a doctor. Another student described that good note keeping minimised medico-legal problems and thought that this was probably not linked to medical uncertainty.

The final category concerning when doctors experienced uncertainty involved how junior doctors resolve their clinical uncertainties at work. One student described a

time when shadowing a junior doctor, and how they observed that the junior doctor chose which senior doctor to ask for *help*, depending on the type of advice that the doctor wanted. This involved the junior doctor understanding the range of responses available.

I was unable to create a hierarchy for the outcome space. I discuss this further in the limitations section in the final chapter (Section 7.2.4).

Table 5.4 - Outcome Space derived from data concerning when medical students believe doctors experience uncertainty

Category	**Description**	Illustrative examples
Unexplained symptoms	Doctors experience uncertainty when they cannot find answers for patients	"A patient comes in very non-specific abdo[minal] pain. Could be a whole world of things." - Mbappe (year 5) "You do all the tests, and they'll come back fine. And someone's in pain. And you have to try and manage their pain as best you can… And that you're not always going to know the answer." - Zeus (year 5)
Ethical and legal dilemmas	Ethical and legal problems create uncertainty for doctors	"I think maybe dealing with the legal side of things sometimes. I think sometimes there are ethical dilemmas that doctors have to deal with, which may go against their own personal views or their own personal values." - Jax (year 1) "Ethical dilemmas would cause a lot of uncertainty." - Uma (year 1) "We've had a lecture given to us by one of the other doctors about the legalities of note keeping and how it can be how it can come back to you legally." - Mbappe (year 5)
Help	Choosing who to ask for help when uncertain	"The F2 was deciding which consultant to speak to about this patient, because she knew that the different consultants would have different approaches. And she basically told me that consultant A will do this… and consultant B is going to do this. And then you know, and she went through all the consultants in the department on the day." - Squirrel (year 5) "I think being a medic is you have to kind of experience uncertainty all day every day from differential diagnosis' to even communicating with colleagues might have a different viewpoint of your viewpoint, and then you're uncertain which one is right." - Charlie (year 1)

Following on from when the students thought that doctors experienced uncertainty, I asked them how they felt doctors managed this uncertainty. Again, these were hypothetical responses. I derived four categories for this outcome space (Table 5.5). The categories were: *enjoy*, *teamwork*, *career* and *quit*.

One mechanism to manage uncertainty (specifically clinical uncertainty) was to view uncertainty as an opportunity, rather than a threat. One student remarked that they saw the approach taken by uncertain doctors working in A and E as being eager to learn from their uncertainty (*enjoy*) rather than allowing the uncertainty to cause any other emotion. Another student remarked that they had heard that it is the uncertainty in the job that creates the challenge and this is why medicine was a fulfilling career choice.

Some students identified practical solutions about how to manage clinical uncertainty in a hospital setting. One student recognised that clinical uncertainty was both complex and common, however, hospitals had a pathway for dealing with this complexity (*teamwork)*. The student had referred to the multidisciplinary team (MDT) meeting, in which complex patients are discussed by many relevant parties and suggestions are made about the best possible treatment for the patient.

A few of the students in years 4 and 5 believed that each of the medical specialties had differing amounts of uncertainty and that doctors who managed uncertainty well would be drawn into those with more uncertainty, whilst those who had a lesser ability to manage uncertainty uncertainty would find areas which had less uncertainty (*career*). The students suggested that, for example, General Practice was a career full of uncertainty; and that any non-patient facing doctor roles had less uncertainty. This was not universally agreed upon with one student suggesting that each speciality would have its own type of uncertainty and that none were entirely free from it.

The final derived category contained conceptions that doctors who could not manage uncertainty would leave the profession. One student suggested that due to

not knowing how to manage uncertainty, or being overwhelmed by the amount of uncertainty experienced daily, a junior doctor might consider *quit*ting medicine. This could be seen as a more extreme version of the earlier category, *career,* except the way to manage uncertainty was by switching careers away from one in the medical field.

I have presented the outcome space with escalating reactions towards uncertainty. With minimal reactions being to enjoy the uncertainty whilst the final category being to leave the profession.

Table 5.5 - Outcome Space derived from data concerning how students believe doctors manage uncertainty

Category	**Description**	Illustrative examples
Enjoy	Uncertainty is unavoidable and makes medicine enjoyable	“I've seen quite a few, maybe I think their senior registrar's in ED. They kind of thrive on these situations.” - Mbappe (year 5) “The one thing that quite a lot of people said is that they embrace the uncertainty, and that's why they kind of love being medics and the challenges that brings every day.” - Charlie (year 1)
Teamwork	Doctors use recognised teams to manage uncertainty	“They literally have multidisciplinary teams for a reason. And they're all taking input from various different sources, and they've all got different agendas and everything.” - Goku (year 4) “If we're talking about uncertainty, in like not knowing what to do right now, in the situation, then definitely like utilising your team utilising your seniors, other people are the brains, more brains the better.” - Zeus (year 5)
Career	Doctors pick a career related to the level of uncertainty they can manage	“So if you're better at coping with it [uncertainty], you may be more suited and happier doing GP whereas if you're not, maybe you're more suited to doing something like immunology or something that's more lab based.” - T (year 4) “Even though you may think that some specialties might have more or less of this kind of medical uncertainty. They all have, quite in their own way, each specialty has their own kind of different factor into it.” - Mbappe (year 5)
Quit	On experiencing uncertainty, some choose to leave medicine	“But I have seen people who actually don't do very well and can cope with uncertainty, and decide quite early on to leave. And I have met a few people who are juniors in like F1 or F2, who at that point, knew that it wasn't for them.” - Squirrel (year 5)
Category	**Description**	Illustrative examples

5.2.4 How did medical students learn to manage uncertainty?

After I asked the medical students how they felt uncertainty was experienced and managed by doctors, I then asked them how they felt they had learned to manage the uncertainty they faced (Table 5.6). The responses were greatly influenced by the amount and type of uncertainty faced by the students, with those in the first year having hardly been exposed to any clinical uncertainty. I was able to derive three categories from the data collected: *student, informal* and *formal*.

The *student* category related to conceptions that students had to identify uncertainty as problematic, or be told by more senior students that it would be something they would encounter and that this was normal. The category suggested that there was no timetabled teaching of uncertainty or any topics that could be related to this, and that learning how to manage this uncertainty was driven by the students themselves, rather than the curriculum or any staff. This category largely contained data from those in first year, who were still in their first few weeks at medical school.

The second category, *informal*, related to conceptions that uncertainty was taught to students, but often via indirect means. This included lectures where the lecturer might deviate from their planned material or from students asking questions to lecturers. Some students also recognised some uncertainty being managed whilst on clinical placements when shadowing doctors.

Finally, there were students who expressed conceptions concerning the *formal*, or lack of formal teaching in the BSMS curriculum. One student in year 5, described how uncertainty was approached in a tutorial, with uncertainty being the focus for that specific small group tutorial. Another student in year 4 suggested that a lecture that they had all attended was about how to manage uncertainty, and said that the lecture was about how to react when uncertain.

I have ordered the categories in order of staff or student involvement, with the least staff involvement/most student initiative at the top and the most staff involvement at the bottom.

Table 5.6 - Outcome space relating to students learning about uncertainty

Category	**Description**	Illustrative examples
Student	Peer support, or student initiated conversations with seniors	"I feel like we've heard it [uncertainty] secondhand from a lot of second year students saying, 'there'll be stuff you don't understand, and that's normal.'" - Emily (year 1) "I don't think we've been taught about uncertainty too much. I think it's a, you have sort of the side conversations with a tutor if you approach them directly. Or if you know that your peers are sharing the same anxieties or uncertainties, you approach them as well." - Jax (year 1)
Informal	Uncertainty being discussed opportunistically by staff or observation of how others manage uncertainty as a way to learn how to manage it	"I don't think it's [uncertainty] really being covered that directly either. Sometimes it's kind of just kind of an offhand comment by the lecturers to say that the content is really difficult, and it will take some time to fully understand, but it's never really addressed that directly." - Uma (year 1) "If you work in A&E, you see a lot of times where some unusual presentations do come up. And then doctors do have to improvise and deal with uncertainty, the way that they would do it just kind of by observing what the juniors do." - Francis (year 5)
Formal	Variation on if students feel they have formally been taught how to manage uncertainty	"[I was taught about uncertainty] in GP in fourth year, but it wasn't in the main lectures. It was by my GP facilitator. Which I imagine would vary with every group and every facilitator." - Zeus (year 5) "Dr. XXXX, he's very big on talking about uncertainty. And that's like, so he kind of drilled it home to us that it's going to be a part of GP life. And so to overcome it, he talked about things like following up and safety netting, but like properly, not just saying `if you get worse, come see me.'" - T (year 4) "There was no mention of, kind of, well, if you're uncertain what to do, and things? I'd say that I don't think there has been any." - Charlie (year 1)
Category	**Description**	Illustrative examples

5.2.5 Should uncertainty be taught and how?

My final set of questions asked the students if they wanted to be taught about uncertainty (Table 5.7) and if they did want to be taught about it how they felt was the most appropriate way for them to learn about uncertainty (Table 5.8). As these questions came at the end of the FGDs, the students had been considering uncertainty throughout as well as different types of educational interventions.

I began this part of the discussion by giving each student the opportunity to describe if they felt dealing with uncertainty should or could be taught (Table 5.7). From their responses, I derived an outcome space with two categories: *Yes* and *Yes if it can be taught*. The students clearly and unequivocally stated that they wanted more teaching about uncertainty if this were possible.

Students from year one wanted uncertainty teaching in the form of recognition that uncertainty was an inherent part of medicine. First-year students described finding their uncertainty stressful and wanted teaching in the form of guidance about who and how to approach seniors when they felt uncertain. One final year student wanted teaching about uncertainty, as having learned that uncertainty was inherent in medicine, they wanted to know how to recognise this type of uncertainty more easily. They wanted teaching to know how they could understand that a medical problem was due to inherent uncertainty rather than simply their uncertainty. These divisions of types of uncertainty were not described by those in year one.

The *Yes if it can be taught* category included conceptions from students who wanted teaching about uncertainty but were unclear if the concept could be taught. One student described how individual a phenomenon uncertainty was and therefore felt it would be difficult to teach. The category demonstrated a desire to have more teaching as well as an understanding and acknowledgement about how challenging this would be for a medical school based on the varied nature of medical learning, which is largely experiential and unique to each student.

Table 5.7 - Outcome space relating to if uncertainty should be taught?

Category	**Description**	Illustrative examples
Yes	Uncertainty should be taught about as talking about it would normalise it.	"I think it's [uncertainty] something that should be included from week one and carry on… I think to have that reassurance that especially at medical school, that there are channels open to kind of acknowledge that uncertainty and challenge it in some ways and address it." - Charlie (year 1) "I think it's just, it just makes you feel like you're not... I suppose a little bit weird for being very, you know, uncertain about whatever. It is just good to be taught very directly, like, yes, you will face this. And this is how you deal with it, or this who to go to?" - Emily (year 1) "I feel like it's important that it's acknowledge straight away and first of all, that you are going to get stressed when you do get stressed this is who you need to go to this is what to do. These are some steps you can take and I think maybe it should be part of the curriculum to have things that de stress individuals." - Jax (year 1) "I think I think teaching would be useful, because I think it's quite hard to get the kind of golden balance of knowing that uncertainty is okay and feeling comfortable or prepared for when you're a little bit out of your depth. But then also not using that as an excuse to sort of get lazy and go, 'Oh, well, I don't know the answer. So I'm going to escalate it to my seniors'. You need to be confident, and you need to have a good basis. That's not an excuse to not keep learning lifelong." - Danny (year 5)
Yes if it can be taught	If there is a possibility of teaching about this then it should be taught	"I don't know if you can teach uncertainty. You can definitely talk about it." - T (year 4) "Every student or doctor would experience it all quite differently, and they would have their own reactions towards it. So I do agree with T that it is quite a difficult subject to teach, even though I believe it should be taught." - Mbappe (year 5)
Category	**Description**	Illustrative examples

The final outcome space I created from the student data consisted of categories relating to how uncertainty could be taught (Table 5.8). This was a hypothetical outcome space of not only what sort of intervention would be beneficial, but also where it should be placed in the medical school curriculum (although this part of the response was only answered by those nearing the end of their time at medical school). I derived four categories from the data: *discussion*, *small group, mixed methods* and *placement*.

Discussion, the first category for this outcome space, consisted of conceptions that uncertainty should be taught through peer discussion. Students commented that those in the year ahead of them would be well or even better placed than the medical school, in understanding the nuances required when teaching about uncertainty. One student also commented that they found students more approachable, forgiving and with more time to give than lecturers. Other students in later years had similar ideas about receiving guidance from junior doctors.

Being taught in *small groups* was another category derived. The nature of the group would be to explore uncertainty on an individual level and discuss how the uncertainty could be managed. This intervention type would allow for real experiences to be shared and all members to contribute and learn. For this sort of learning, the students believed that they probably had between them the knowledge needed to resolve most situations. One student from year 4 expanded on this and suggested that these groups could be facilitated by doctors, with one of the goals being to allow students to understand how doctors experience and manage their uncertainty.

One of the students from year 4 believed that learning about something so complex probably required a number of different interventions. I have labelled this category *mixed methods*. This student appreciated that not only was there not a single way to learn about uncertainty and that variety was important as not all students were the same. The student suggested a number of different interlinked interventions which would all hopefully allow for the majority of students to learn how to manage their

uncertainty, with the opportunity to both think about the phenomenon and ask relevant questions which would help them further understand it.

The remaining category in the outcome space concerned the *placement* of uncertainty teaching. This question was only posed to those in the final years of the curriculum as they were more suitably placed to understand how the medical school functions, and where any teaching might fit. There were a variety of conceptions about where to place uncertainty. Some students felt you could and should integrate uncertainty throughout, either to mirror how clinical work actually was or because different students would appreciate clinical uncertainty at different times. One student (year 5) remarked that medicine is full of “grey areas”, which contain much inherent uncertainty. The student felt that teaching about how to manage uncertainty could be included when discussing these areas even from the start of the course. Other students in years 4 and 5 felt that teaching about uncertainty would be irrelevant or un-understandable to those yet to experience clinical medicine and therefore the focus should be on students in clinical years.

As this outcome space is an amalgamation of both type and timing of possible teaching, which are logically related, it is presented without any observable hierarchy.

Table 5.8 - Outcome space relating to how uncertainty could be taught about and where it fits in the medical school curriculum

Category	**Description**	Illustrative examples
Discussion	Discussion with peers, tutors or junior doctors sharing real-life experiences	"We were given medic families… But I feel that that role is more akin to the stereotypical tutor role where when you need guidance, they're there… I find it way easier to talk to someone in the year above who has gone through it." - Charlie (year 1) "There are a lot of F1s who are uncertain about a lot of things and they're there at their day-to-day jobs, and actually experiencing that [with them] and seeing how they go forward." - Francis (year 5)
Small group	Small groups allow for sharing of personal experiences and group reflection	"Maybe small group teaching would probably be the best, because it allows you to share your own experiences, allows other people to also share their experiences on a more personal level." - Mbappe (year 5) "I agree that like small group teaching… where more experienced doctors could talk about their experiences with uncertainty how they cope with it. I think that might be helpful, just more like normalising it then teaching us." - T (year 4)
Mixed methods	Students require different interventions	"Yes, I feel like it should be done in a variety of different methods, because I feel like people respond differently. So like, yeah, maybe have a sort of a broad lecture that covers it with signposting where to go and then it should be further explored specifically in small group settings. Because I feel like that's where most people will be able to ask all the questions they want, if that makes sense." - Goku (year 4)

Placement	Uncertainty should be taught from the start, throughout or only during the clinical years	"Why not introduce the grey areas in the uncertainty from early? Beginning like from the start?" - Squirrel (year 5) "I think everyone, yeah, encounters uncertainty with the medical career at different points. So I think having it trickled throughout medical school would be really useful." - Danny (year 5) "So we do anatomy, pathology, physiology, pharmacology, and everything else around, for example, cardiology, we could look into sort of grey areas, so uncertainty around like cardiac problems, and we looked at we could look at cases, and then that could be incorporated into every system." - Squirrel (year 5) "[If uncertainty was discussed too early] It will be like, 'What are you talking about? We always know the answers.' I think it takes seeing it in practice, or like hearing first hand stories and being a bit older to really appreciate what happens, I think, yeah, young juvenile mind wouldn't have appreciated it at all. But everyone's different. And I was just like that when I was 19." - Zeus (year 5) "I think third year, or maybe? Yeah, I think third year, I think even the end of second year is too early. I think it really comes into play in when you're doing more clinical based learning. And when you've got more experience in hospital. I think it'd be hard to apply in second year, I think people might dismiss it in second year." - Danny (year 5)
Category	**Description**	Illustrative examples

5.3 Discussion

5.3.1 How did the students conceptualise uncertainty and when did they experience uncertainty during their training?

Asking the students how they both conceptualised uncertainty and when they experienced it were challenging opening questions for all of the focus groups. The categories I derived from the conceptualisation data: *action, emotions, inherent* and *acceptance*, demonstrated diversity in both understanding and experiencing of the phenomenon. Thankfully, the discussion promoted by the focus group format helped students expand on previous comments and allowed the students to further develop and justify their responses, which added much richness to the data.

The fact that some students felt that uncertainty was only apparent when they were required to take action themselves, implies that teaching would be more impactful if the students are required to take actions. This could be in a safe fail environment such as simulation or while supervised clinically. One student even commented that (from FGD 1):

> *"I think because I don't have to make decisions about patients' management, I don't think that uncertainty is something that affects me directly."* - Squirrel (Year 5)

When discussing uncertainty, the students rarely talked about this in the context of patients. The lack of inclusion of patients in the data meant that students rarely expressed the inherent uncertainty of clinical medicine, which was different from the conceptualisations of the educators. With this finding, I felt that the full comprehension of the ubiquitous nature of uncertainty in medicine was absent from the majority of the students' responses. Unlike the educators, conceptions about certainty were not discussed.

The response of feeling anxious when uncertain reflects what has been found elsewhere in the literature by those studying tolerance of ambiguity (a cause of uncertainty) and well-being (Hancock and Mattick 2020; Hillen et al. 2017). Students also frequently expressed feelings of guilt about both taking up patients' time and hospital resources unnecessarily. These expressions of shame and guilt have been seen before in the literature (Bynum et al. 2021; Greenmyer et al. 2022; Bynum and Goodie 2014). These concerns should probably also be addressed at some point, although these are more likely linked to the students' own sense of self-worth rather than more general uncertainties. Self-acceptance in the face of uncertainty has been explored before in research by Nevalainen et al. along with fear of making mistakes and insecurity of professional skills (Nevalainen, Mantyranta, and Pitkala 2010). The excitement expressed by one student to facing so much uncertainty with close peers, speaks of the social nature of medical students and learning, and might describe the start of medical identities (Goldie 2012).

The inherent nature of clinical uncertainty and what this truly meant was realised by some of the year 4/5 students. This transition, from feeling medicine was black and white, largely because this is how it has been taught, to starting to understand that there are no absolutes and starting to grasp alternative ontological stances, was clearly expressed by Mbappe (year 5) in the outcome space (Table 5.2 - Category *Inherant*). This is not a new finding, having been seen already in this work by Samuel (the educator expressing it, Table 4.4), with Knight and Mattick, Haas and Stojan, and Land arriving at similar findings (Knight and Mattick 2006; Land 2016; Haas and Stojan 2022):

> "A pedagogy of uncertainty comes to mean that learning for uncertainty means learning to live with uncertainty. Similarly, such pedagogies cannot dispel anxiety, but seek to provide students with perspectives that will enable them to live with anxiety. As Barnett puts it: The ice is perpetually slippery but this says nothing about the individuals on the ice, only about the conditions of epistemological insecurity in which they now find themselves.

> But this epistemological slipperiness generates, in turn, ontological destabilisation. For if the world is radically unknowable then, by extension, 'I' am radically unknowable." - Ray Land (2016, 224–225)

The sources of uncertainty or where students experienced uncertainty should also help focus any teaching about uncertainty. I found that the sources of uncertainty between the first and the final years differed greatly. Those in the first year had much personal uncertainty about if they were suited to medicine, their own abilities to learn new skills and concerns about the amount of knowledge they would surely have to obtain. These responses might have been tainted by the fact that the first-year students were in the stages of revising for their first summative assessment whilst those in their final year repeatedly talked about their future in the medical profession. Surprisingly, having committed such a large amount of time in medical school, many were unsure if this was a career suited to them. For some, this might have been a coping mechanism, as they had yet to take their final exams and it would allow them some alternative route should they fail. For others, there was genuine concern that the vocation of medicine no longer aligned with their personality. These uncertainties were expressed by the educator Wilko when considering when they thought students experienced uncertainty (repeated quote from Table 4.8):

> *"Uncertainty, whether they'll make the grade… Uncertainty about whether they really want to be a doctor at all."* - Wilko

These findings, the sources of uncertainty for medical students, are similar to findings by Stephens et al. from their paper 'A whole lot of uncertainty', which was a qualitative study of medical students' experience of uncertainty in Australia (Stephens, Sarkar, and Lazarus 2022). This research found that students suffered from three broad types of uncertainty. Firstly, educational uncertainty, which is uncertainty relating to what, how much and how to learn in a clinical environment. I found the same uncertainties expressed by the students in the year 1 focus group about learning new knowledge and skills. Similar findings were made by Konkin and Suddards with their more general qualitative look at clerkships concerning limits of

expected knowledge by students (Konkin and Suddards 2017). Secondly, professional uncertainty, which concerns questions about the professional identity formation of students. This was what I called the *future* category which was expressed by the final year students in focus groups 1 and 2. The difference between my findings and those of Stephens et al. were the students I interviewed frequently expressed a desire to explore areas allied to medicine (such as working for pharmaceutical companies) rather than following traditional medical careers. Finally, there was clinical uncertainty, which was uncertainty relating to patient care and the inability to express precise answers. As with my findings, Stephens et al. noted that these uncertainties were expressed least of all, although their students were in years three and five and were all experiencing clinical medicine rather than the students I interviewed who were in years one,four and five and experiencing a mix of teachings.

I managed to generate a much larger outcome space from the hypothetical ideas of the medical educators about when students experience uncertainty (Section 4.2.3.1), than from the actual responses of the medical students. One of the main responses of the educators was 'all the time' when asked when students experienced uncertainty. This led to educators considering most aspects of medical training being a source of uncertainty and was perhaps why they were able to list more ideas than the medical students. This answer was not replicated during the student focus groups. Reassuringly, this would suggest that students are perhaps less uncertain than medical educators believe they are. I have created a Venn diagram to illustrate the similarities and differences between the perceived uncertainties of medical students and the actual uncertainties described by medical students.

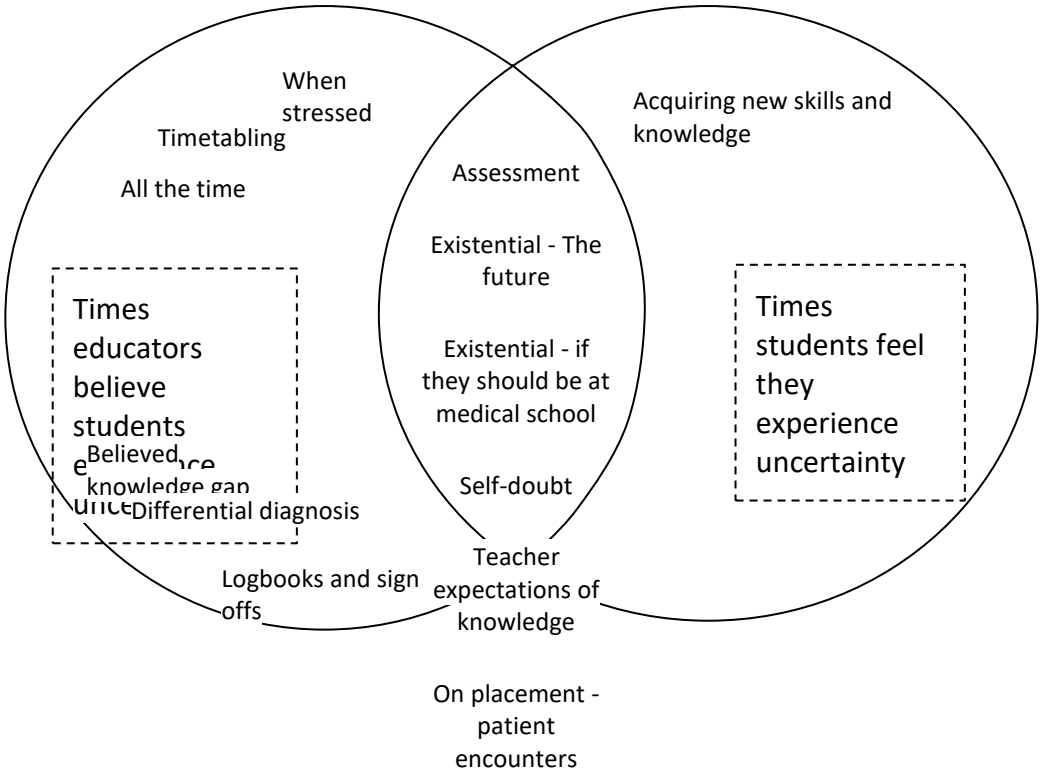


Figure 5.1 - Venn diagram of medical educators' perceived times of when medical students experience uncertainty and actual times medical students are uncertain

Many of the first-year medical students expressed doubts about their abilities to learn the volume of information required to pass summative and practical exams. This was not a concern of the fourth and final-year medical students, who must have passed many exams to have entered the fourth or final year. The thoughts of one of the medical educators are relevant here when he said (from interview 11 with Samuel):

> *"I think part of medical school training is teaching you to hide it [doubt and uncertainty]. And teaching you to 'fake it till you make it'." - Samuel*

The students from the final two years of the course were now in a position where they knew how to appear confident, so even if they had not learned all the material required to pass the exam they had confidence in their actions. They had learned to 'fake it'.

For the medical students, when they thought about uncertainty and where or when it affected them, it was largely about their personal uncertainty. Broadly this is very different to how uncertainty was conceived by the educators who spoke rarely of the individual effects of uncertainty and tended to focus on the inherent nature of uncertainty in clinical practice. The similarities between all those interviewed were the emotional reactions towards any uncertainty faced, which suggests that even though uncertainty was experienced differently there was still a powerful emotional reaction when experiencing the phenomenon.

5.3.2 When do doctors experience uncertainty and how do they manage this?

Asking the students when they thought doctors experienced uncertainty and how they managed this was the reciprocal of the question "When do students experience uncertainty?" posed to the medical educators. The data reiterated a lack of clinical exposure for the medical students. There were also many dramatic answers to the question, such as doctors *only* experiencing uncertainty when they had to act in ways which they disagree with morally or when they had legal concerns over their duties or indeed manage their uncertainty by leaving the profession. There were fewer responses by those in year one and this was perhaps an unfair question for those students.

There was a belief by some that different medical specialities required different tolerance levels towards uncertainty. The students discussed A and E and General Practice and other specialties where a greater tolerance of uncertainty was needed and suggested that perhaps non-patient facing doctor roles required less tolerance. These responses moved a few of the students towards accepting that some uncertainty was inherent in medicine and it was simply tolerance (or intolerance)

towards this uncertainty that naturally aligned doctors with their career choices. The students debated if this was true (conversation from Focus Group 1).

> *"I don't know, in radiology see an image, and you describe an image, and you describe what you can see, and you don't really see, or you don't have access to much more than that."* - Squirrel (Year 5)

> *"So I think, even though you may think that some specialties might, might have more or less of this kind of medical uncertainty, they all have, quite in their own way. Each specialty has their own kind of different factor into it."* - Mbappe (Year 5)

Findings that tolerance for uncertainty can be linked to career choice have been seen elsewhere in the literature, with some finding an intolerance of uncertainty is linked to surgical careers (Borracci, Ciambrone, and Arribalzaga 2021). Others have suggested that students should be informed that their ability to tolerate uncertainty is both a strength and a weakness and that students should be advised which careers might have a greater need for such a skill (Reis-Dennis, Gerrity, and Geller 2021).

5.3.3 How did medical students learn to manage their uncertainty?

As medical students experienced, conceptualised and described managing uncertainty very differently from those in medical education and from the literature concerning clinical uncertainty, the responses given would need careful consideration about how this might contribute to the pedagogy concerning the teaching of this subject. However, the students' conceptions were still important as they identified ways that they feel have been the most effective or appropriate in learning the management of uncertainty.

The question, how did the medical students learn to manage their uncertainty, was a difficult question for those in their first year to answer. Their minimal time at

university, as well as lack of clinical experience, meant that their overall comprehension of the uncertainty that doctors faced would always have been limited. If anything, the responses show how different medical students are at either end of their time at medical school, with awareness of problems increasing with experience. The first year responses to how they felt they learned to manage uncertainty tended to focus on peer-to-peer or near-peer teaching and generating a network of contacts that could be relied upon later. This would suggest a social constructivist theory to knowledge acquisition. In this theory knowledge is developed through interactions with others and groups rather than with the natural world or observations (McKinley 2015).

The students' recognition and understanding of how to manage uncertainty tended to be self-motivated and self-determined. Understanding that intrinsic awareness is a powerful driver of learning has been described by self-determination theory (Ten Cate, Kusurkar, and Williams 2011). The theory describes that students who have their autonomy supported go on to form more long term memories and have better educational outcomes (Williams, Saizow, and Ryan 1999). The theory might also describe why those who are yet to experience clinical uncertainty, would struggle to learn about it, as they would not be intrinsically motivated to solve this issue.

The informal methods described by some students, that learning about uncertainty occurred due to student enquiry or away from the planned assignments, echoes what was said by many of the educators about how they felt they taught students about uncertainty. An informality might be necessary when teaching about an area with such complexity, as a nuanced approach or displaying vulnerability might help students transition through the threshold. This informality - learning about the management of uncertainty through shadowing doctors during clinical placements - was similar to the category *other* which contained conceptions of how the educators felt they had learned to manage uncertainty (Table 4.5). It also was discussed by Mipha in the category *necessity*, when describing how uncertainty was necessary when learning (Table 4.3). Of note, none of the students felt that they could not manage the uncertainty they faced, or at least were unwilling to discuss this in the

group setting or with me. These more informal methods have not been described in the literature when discussing how to teach medical students about uncertainty, where all methods were intervention based (Patel et al. 2022).

There was no agreement amongst the students in years 4 and 5 about what constituted formal teaching about uncertainty. Some felt that lectures given by general practitioners on topics such as how to 'safety net' a consultation, were in fact about the management of uncertainty whilst others could not see the link between the lecture given and uncertainty. This is why trying to teach via indirect methods can be problematic as the outcomes from the teaching could be missed or misinterpreted. Whether teaching was direct or indirect, the students felt that very little time had been dedicated to this issue during their undergraduate training.

The methods described by the students about learning how to manage their uncertainty differed considerably from both how the medical educators had felt they had learned to manage uncertainty and how a study had described when they learned to manage uncertainty (Papanagnou et al. 2021). Educators described reflection, observation and time or experience spent in a clinical setting as being how they learned this skill (Section 4.2.2). These differences are not surprising considering the difference in the orders of magnitude of time spent dealing with uncertainty. As for the literature, Papanagnou et al. found with their observational cross-sectional study of third-year medical students, that students felt they had learned to manage uncertainty from simulations, storytelling, role-modelling of communication strategies and debriefing (Papanagnou et al. 2021).

5.3.4 Should uncertainty be taught to medical students and how?

Unlike for the medical educationalists, the students did not find it difficult to answer the question whether more teaching about uncertainty should be included in the medical school curriculum. The students were in universal agreement that they wanted more teaching. This is probably not a surprising finding as I envisage that all

students would agree to have more teaching on a topic that they find challenging, especially in a self-selecting group. Danny (year 5) in Focus Group 2 described the dissonance experienced when learning to manage uncertainty:

> *"I think teaching would be useful because I think it's quite hard to get the kind of golden balance of knowing that uncertainty is okay and feeling comfortable or prepared for when you're a little bit out of your depth. But then also not using that as an excuse to sort of get lazy and go, 'Oh, well, I don't know the answer. So I'm going to escalate it to my seniors'. You need to be confident, and you need to have a good basis. That's not an excuse to not keep learning lifelong."* - Danny (year 5)

Danny described some of the requirements of being self-reflective, and how acquiring the ability to learn through self-reflection is fundamental to being successful in medical practice, as well as starting to understand the differing expectations placed upon them (Ménard and Ratnapalan 2013). Danny was describing the development of a decision tree, much like the educators did (Table 4.4), when they were uncertain and could either ask for help or attempt to problem solve by themselves. This shows Danny's maturing of understanding of uncertainty and the transition from having epistemic uncertainty into managing aleatoric uncertainty.

The placement of any such intervention was also an area of debate with some students expressing longitudinal or spiral suggestions (although not using that nomenclature) and others targeting a specific time following an amount of clinical exposure (Harden 1999). These mixed findings were similar to those of the educators (Table 4.12).

A few of the students agreed with some of the educators that uncertainty could not be directly taught - (Table 4.9), but still wanted more insight into the phenomenon and how to manage it. These conceptions were included in the *Yes if it can be taught*

category. Mbappe (year 5), with a concise retort (Table 5.7), described the difficulties with teaching such an individual phenomenon (repetition from table).

> *"Every student or doctor would experience it all quite differently, and they would have their own reactions towards it. So I do agree with T that it is quite a difficult subject to teach, even though I believe it should be taught."* - Mbappe (year 5)

As for how uncertainty could be taught, the findings were largely in keeping with what had been said by the medical educators and also mirrored the diversity of methods currently in the literature (Patel et al. 2022). There was repetition that no single way would suit everyone and also that the lectures were probably not beneficial. Gestalt learning theory is what the students were expressing here, a learning theory which emphasises learning as a whole based on the learner's own experiences (Nalliah 2014). Those who advocate for the theory suggest that all individuals have their own way of understanding a problem as well as ways of perceiving and arranging information and therefore there is no single way of teaching something complex.

These findings carry implications for effectively teaching students about uncertainty. Firstly, teaching should be tailored to the specific needs of the year group. First year students need more generalised advice on how to thrive as a student, to have clinical uncertainty be recognised and normalised by educators and be taught how to find strength in their own different abilities. The lesson might simply be normalising the uncertainties faced during pre-clinical sessions or providing a space or contact to message when students feel they require it. The teaching could come from peers as well as members of the medical school, as peers had previously been found to be beneficial when learning certain skills, since peers are more likely to understand the critical elements needed (Riddell and King 2016). Secondly, for teaching those in final year groups, broad advice on the lack of certainty throughout career progression seemed relevant, as well as a few other specific clinical uncertainty management skills (more details in Section 6.4) (Gheihman, Johnson, and Simpkin 2020).

Some students had concerns that any teaching might simply be 'box ticking', and that the teaching should be delivered in a way that students were receptive to (from focus group 1):

> *"But if it was to be taught, it should actually be taught with like the right intention rather than just being a box-ticking exercise. Because I feel like, for example, me personally, Zeus said she hadn't been taught any ways to manage her anxiety. In first year, we had a 'lovely' session on mindfulness where, where there's some bald gentlemen came in and hit a little bowl with a little gong thing and made it made a really nice humming noise. And we all sat there in silence and closed our eyes. But I just I feel like that was just for the sake of it rather than actually for anything."* - Goku (year 4)

This example clearly highlights the drawbacks of trying to teach to an audience who are not receptive or motivated, which had been noted in the findings of a few of the previous studies which used alternative methods to try and teach medical students about uncertainty (Liou et al. 2019; Bentwich and Gilbey 2017). This perspective was also suggested by many of the educators in their category *Stealth* (Table 4.13), but instead approaching the novel teaching from the perspective of the student.

This discussion has reviewed and analysed the data I collected from the students and has integrated some of the findings from the educators. The students were opinionated on the area and arrived at, through the discussion group, some sophisticated findings about all aspects of uncertainty. Based on this data I have made some further recommendations which aim to add to or modify those in the previous chapter.

5.4 Summary and recommendations

As with the previous chapter, I will begin by summarising the data collected from the medical students in the context of the original research questions.

1. What is meant by uncertainty and how is it currently taught in medicine?

- Uncertainty was considered both an individual problem as well as an issue that arose clinically when confronted with a decision or the need to take an action.
- Early-year students felt they were not taught by the medical school how to manage their uncertainty and learned how to manage their uncertainty from their peers.
- Later year students occasionally recalled formal teaching on how to manage uncertainty but felt the main learning had always come from student-initiated questions or enquiries.

2. What do medical educators and medical students think about uncertainty?

- Students were uncertain about their own abilities or future capacities as doctors.
- Students also expressed uncertainties about the commitments of being a doctor.
- Students unequivocally want to be taught about uncertainty.
- Doctors were thought to experience uncertainty when encountering new problems or pathologies, or during ethical decision-making.
- Doctors were thought to manage their uncertainty by asking for help, treating the uncertainty as an enjoyable challenge or selecting a career which was appropriate for the amount of uncertainty they could manage.

3. What do these findings mean for uncertainty in medical education?

- Clinical uncertainty is a threshold concept that those starting their medical training are unlikely to be aware of.
- Clinical uncertainty needs to be experienced and normalised before it can be accepted and students can learn from or about it.
- Teaching students about uncertainty needs to be carefully tailored depending on the student year group.

Based on this data, some further suggestions can be made concerning the details of how to teach the management of uncertainty:

1. Some unambiguous teaching around the clinical uncertainty phenomenon is required, ideally through conventional methods (a staff approach).
2. Those who have just started their medical degree need to experience clinical uncertainty before they can be advised on how to manage this, or they will not likely comprehend the ubiquitous nature of the phenomenon. This should include the addressing of uncertain pathologies in lectures and the general normalisation of uncertainty during clinical medicine placements.
3. Students should be encouraged to engage in inter-year peer groups, to learn how to manage this phenomenon and others (a student approach).
4. For those further along with their training, small group teaching is advised, where individual problems, such as being guided through ontological differences, could be addressed by someone more senior.

The medical students added much-needed insight into the comprehension of uncertainty at different levels of clinical experience, which has allowed me to be more specific with my recommendations. They also highlighted why certain teaching methods might be poorly received, largely due to a lack of comprehension and unrelatability of the problem domain.

5.4 Concluding thoughts

The medical students added much needed relevant insight into how the phenomenon of uncertainty is perceived as well as real understanding of the difficulties in having to teach about it. How this perception changes is highly relevant for tempering future educational interventions. In my final chapters, I discuss how to incorporate these findings into medical school teaching, summarising the critical elements from all of the data, and fully answer my original research questions.

6. Synthesis

In this chapter, I have answered the three research questions and discussed the insights I have gained from the research. Drawing on the synthesis of the analysis of data from this project, a review of extant literature, and experience from practice, I have constructed a number of conceptual frameworks and have drawn on these insights to propose a methodology for practically teaching the management of uncertainty. I have finished the chapter by evaluating the validity of my findings based on my prior measures. This chapter leads directly into the final chapter - Conclusions.

6.1 Answering the research questions

I have integrated the findings from the literature review, medical educators and medical students to arrive at concise answers to my original research questions. These could be considered the critical aspects for learning about the phenomenon, which is one of the strengths of using this methodology (Åkerlind 2015). Below this, I have created a final outcome space to summarise these findings (Table 6.1).

1. What is meant by uncertainty and how is it currently taught in medicine?

- Uncertainty is a threshold concept that is both poorly conceptualised and hard to define. Uncertainty in general is experienced by medical students when considering if they are suited to medicine or if medicine is suited to them.
- Clinical uncertainty is a phenomenon that emerges when an action needs to be taken in a clinical context when there is a lack of precision for the response or an unknown or unknowable outcome.
- There have been a variety of ways uncertainty has been taught about, including role modelling, shadowing, debriefing, simulation and using more novel teaching methods. Teaching largely consists of creating some uncertainty and

evaluating the reaction towards this, demonstrating how to manage uncertainty in a clinical setting or ways to reduce uncertainty in clinical situations or self/group reflecting on times when uncertain.

2. What do medical educators and medical students think about uncertainty?

- Uncertainty is an inherent part of medical practice. Learning to manage uncertainty is a requirement of all those in healthcare. There are different techniques needed and these are largely developed during clinical practice.
- Educators described the management of aleatoric uncertainty, where outcomes were numerous but foreseeable.
- For medical students, uncertainty was a personal phenomenon. The phenomenon was related to their capabilities in learning how to be a doctor or if this is the right vocational choice for them. Uncertainty was largely described in terms of epistemic uncertainty when expectations were unknown. As they were starting to identify clinical uncertainty as something that would soon be problematic for them, they wanted more teaching about how to manage it.

3. What do these findings mean for uncertainty in medical education?

- Clinical uncertainty is a threshold concept that those starting their medical training are unlikely to be aware of.
- Most educators thought that medical students should be taught explicitly about the uncertainty that they will face and be taught that such uncertainty is normal. Some thought this should only occur when it became relevant to students. However, some doubted that it could ever be done in a constructive manner.
- Clinical uncertainty needs to be experienced before students can learn from and about it.
- Variation in methods was considered important because just as there is no one type of uncertainty there is also no single way of teaching students about it.
- Teaching students about uncertainty needs to be carefully tailored depending on the student year group.

Table 6.1 - Outcome space for research

Category	Year 1 Students	Year 4 or 5 Students	Educators
Uncertainty is about	The individual - Am I good enough? Moral, ethical and legal dilemmas	The individual - Making decisions when you do not have enough knowledge. Do I want to do medicine as a career?	Patients and the team - Knowing the expectations of others and how to meet these. An enjoyable part of the job
Types of uncertainty	Only epistemic	Largely epistemic	Mixture of epistemic and aleatoric, but mainly aleatoric
Should medical students be taught about uncertainty?	Yes	Yes	Maybe
How can it best be taught or learned about?	From peers	Guided group discussion	Group and individual reflection or through experience in a safe learning environment.
When should it be taught?	Students not questioned on this area	At the start of, or just before clinical exposure	Requires clinical exposure. Throughout medical school to a postgraduate area.

6.2 Research insights

- Current trends in the literature discuss the tolerance of uncertainty, which implies that uncertainty is a negative passive attribute (a person's state). I have re-framed this as management of uncertainty, which has more positive and active connotations (a modifiable trait).
- Uncertainty can be uncomfortable whereas inappropriate certainty is dangerous. Treating uncertainty as an opportunity to learn from, rather than a personal threat, can reduce the burden suffered from uncertainty. This would both normalise uncertainty and provide direction for those experiencing it.
- There is a disconnect between educators' conceptions of uncertainty, which is largely aleatoric and students' experiences of uncertainty which is largely epistemic. It appears that with greater understanding and knowledge the type of uncertainty experienced transitions between epistemic and aleatory uncertainty.
- Thus learning to manage uncertainty occurs over time and the accumulation of a variety of different and individual personal experiences and skills. Mastery of these skills often requires the input and insight of others. Learning about uncertainty also inadvertently introduces students to the philosophical concepts of ontology and epistemology which they may not have had the opportunity to consider before.
- Students who have not experienced clinical medicine are unlikely to be aware of how doctors suffer from clinical uncertainty.
- Students only start to appreciate clinical uncertainty when they are required to make decisions and trying to teach students about clinical uncertainty before they have experienced a clinical environment, would likely be futile.

6.3 Conceptual frameworks

Throughout this work I have always tried to maintain a sense of perspective. I have created two conceptual frameworks and one diagramto try and capture the essence of this research and I have displayed them below.

Figure 6.1 depicts the conceptualisation of uncertainty as a threshold concept. During the research, some participants described uncertainty on a spectrum of subjectivity and objectivity (although this itself could be considered subjective). Ideas about what uncertainty meant to the participants are divided with some at one end viewing uncertainty as a part of them (subjective uncertainty), whilst others see it as an inherent part of medicine (objective uncertainty). The centre of the framework contains a theoretical threshold that needs to be traversed before inherent medical uncertainty is understood. There is of course much overlap in ways to manage and sources of uncertainty and the threshold drawn is artificial as are the concepts of what is actually subjective and what is objective. The figure broadly demonstrates the transition made in beliefs about uncertainty once the threshold has been crossed.

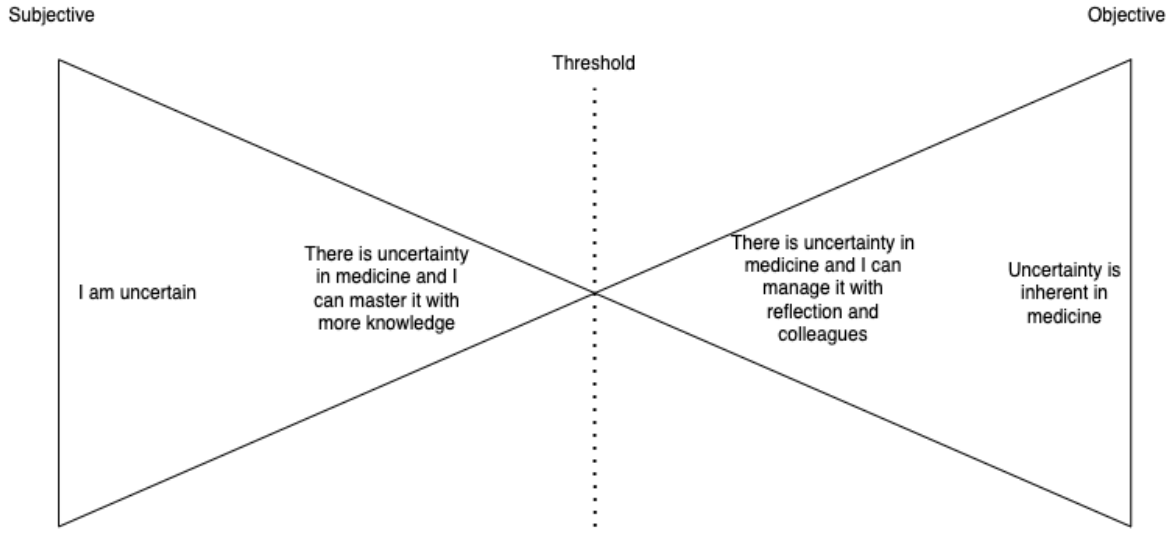


Figure 6.1 - A conceptual framework of the threshold of medical uncertainty. Uncertainty is presented as a spectrum with subjective uncertainty on the left and objective uncertainty on the right. In the middle lies a threshold where uncertainty is no longer considered a subjective phenomenon once the threshold has been crossed. The middle of the framework contains ideas about how uncertainty relates to the individual

Figure 6.2 presents a figure concerning the different viewpoints about teaching and learning of uncertainty. The figure starts with methods that educators say they have used to teach students about uncertainty. Centrally there are descriptions used by doctors and students expressing how they feel they have learned about uncertainty, and to the right of this are potential methods to teach uncertainty. What has been, what is and what could be. The figure can be used to describe the discrepancies between teaching and learning.

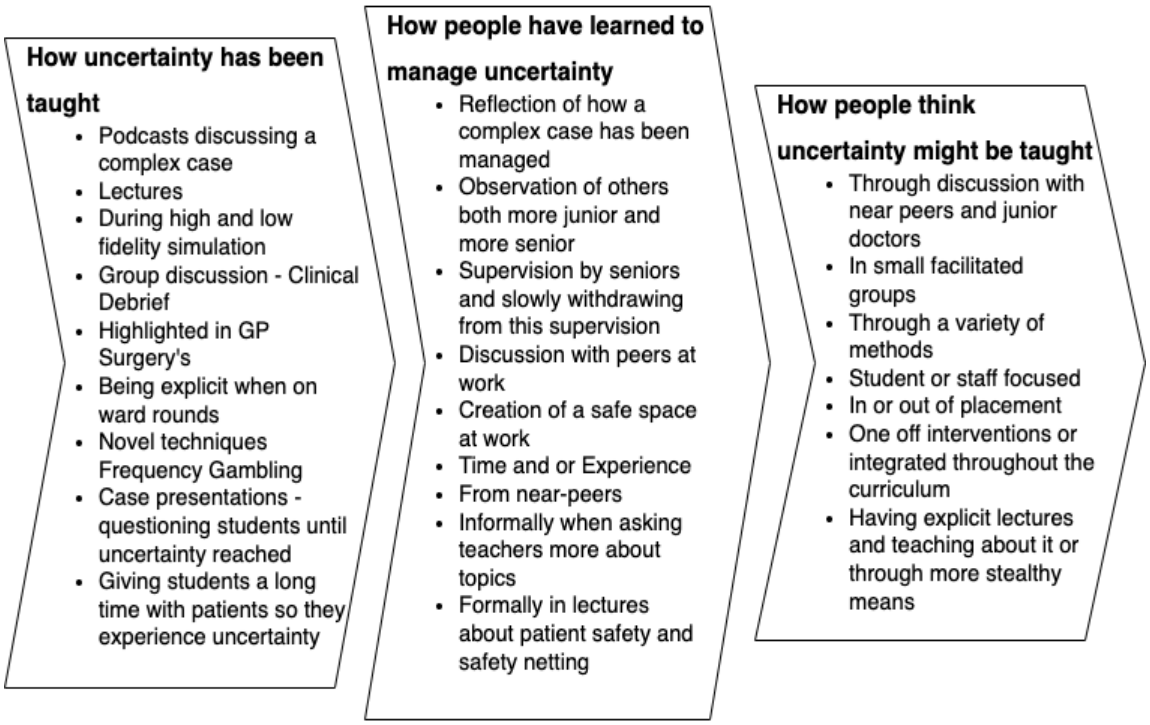


Figure 6.2 - A diagram showing the differences between the teaching of and the learning of uncertainty. How educators have taught about uncertainty followed by how participants learned about uncertainty followed by how educators think it might be taught

Figure 6.3 depicts some tentative ideas about the phenomenon itself and how it relates to medical education. The phenomenon is presented centrally, whom it concerns is the surrounding ring, and their thoughts on uncertainty or how they think it can best be learned are the outermost ring.

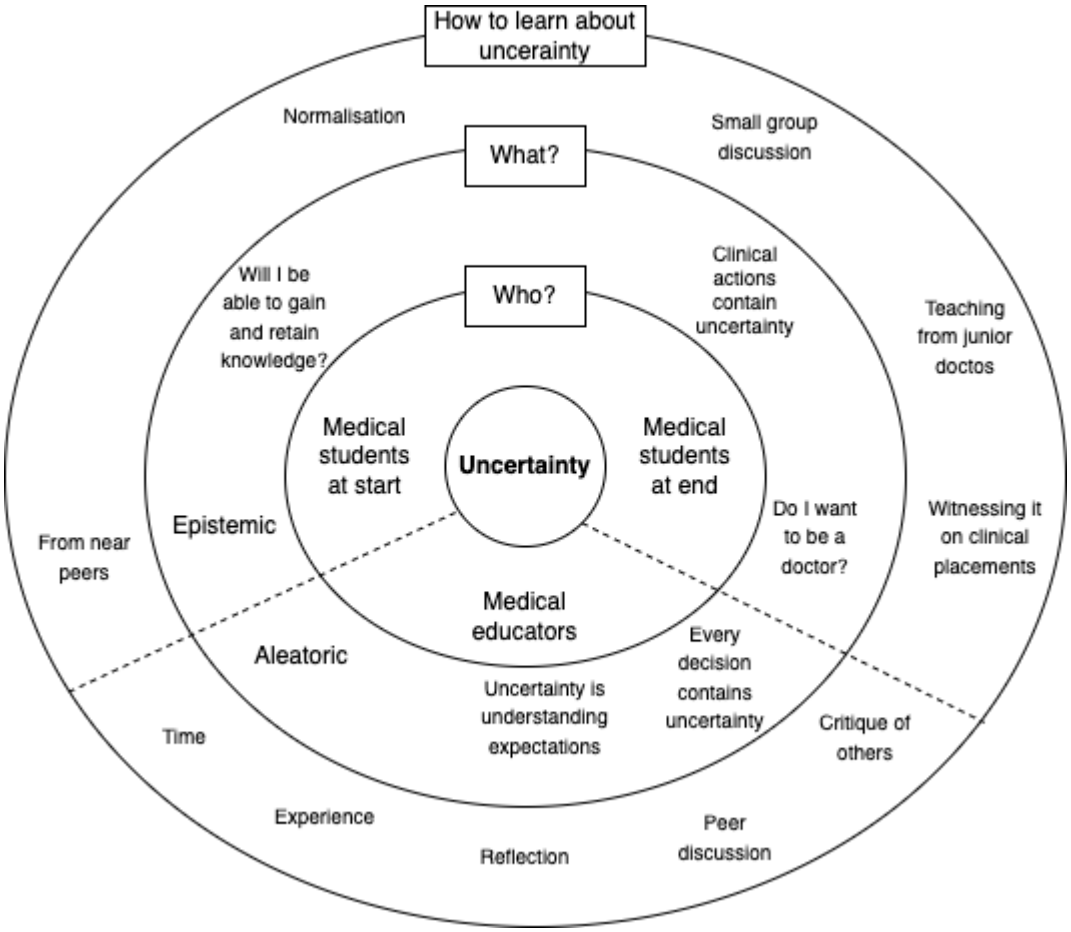


Figure 6.3 - A conceptual framework of what the phenomenon of uncertainty means to medical education and how it could be learned, from the perspectives of medical students and educators

6.4 A methodology for developing uncertainty management skills

I have proposed a methodology for managing uncertainty. The details were constructed from suggestions by Gheihman et. al from their 'Twelve tips' article[24] on the area as well as my own research findings (in italics) (Gheihman, Johnson, and Simpkin 2020). Below I have detailed the practical recommendations allied to this method, which could be done in a clinic, ward or simulated environment. Much of this example is already done in routine clinical practice.

a) Identify uncertainty and *do not accept certainty prematurely*

The first stage to managing uncertainty is to identify that there is uncertainty. How this uncertainty manifests will be different for every person, but it could be considered a lack of certainty in knowing what actions to take. Teaching around this area should be about students not accepting their first idea and instead embracing the uncertainty of the situation. Role modelling how to communicate when uncertainty in front of patients could be used to do this as well as demonstrating how to create an appropriate differential diagnosis list.

b) Minimise ambiguity *and clarify expectations*

I would argue that the traditional medical consultation - history taking, examination, investigations and planning - is designed to try and minimise ambiguity[25]. Students should be allowed to conduct consultations and be taught how to ask relevant follow-up questions in a way that minimises any ongoing ambiguity. This involves understanding what may or may not be relevant when taking a history. Curiosity should be promoted over result-seeking. Teaching students the reasoning behind why each investigation is requested is important. For example, a plain radiograph can help further minimise ambiguity in symptomatology rather than purely as a baseline when entering a hospital.

[24] Which itself is a review article encompassing many other theories

[25] From my experience and others, a typical initial consultation is constructed in a logical way that starts broad and allows for the exploration and either inclusion or illumination of possible pathologies (Custers, Boshuizen, and Schmidt 1998).

Students should also be taught to manage the expectations of patients, as this can also be a source of uncertainty for the student. Asking patients about their expectations from a consultation can help students reduce their own epistemic uncertainty, as the priority of the consultation should be meeting these expectations which can focus the student's reactions. In addition, understanding what a patient's expectations are is important as these might not be realistic, and therefore need to be adjusted early. Having a conversation about expectations may have a co-benefit of reducing the amount of uncertainty suffered by the patient.

c) Speak with others *and gather their knowledge and opinion on the uncertainty*

Having gathered some initial information and started a reasoning process towards a likely diagnosis, students should be encouraged to check if this aligns with what others think. Demonstrating this in clinical situations, by discussing cases with colleagues, would again allow students to appreciate that it is normal to have uncertainty in medicine.

d) Be honest about the uncertainty with the patient and perform shared decision-making *with patients*

After discussing the uncertainty and not arriving at a single solution, discussing this uncertainty openly with the patient should be the next course of action. This might further clarify the patient's needs or wishes putting them at the centre of their care. Again, this could be highlighted and described and then demonstrated by senior clinicians in front of students. A discussion of possible options, all under the context of uncertainty can be made with the patient, so their wishes are preserved.

e) Plan for multiple eventualities

One of the key outcomes of taking a medical history is to arrive at a differential diagnostics list, which allows a practitioner to direct specific efforts correctly

(Hampton et al. 1975; Ingram 2017). The fact that it is described as a list rather than a single diagnosis speaks to the inherent uncertainty of medicine. How the patient is managed will depend on what is on the differential diagnosis list, and often multiple actions will need to be taken which will corroborate or reduce the chances of the problem being caused by a particular pathology. The management of the multiple possible pathologies should be done in parallel, depending on what that management involves and how problematic the pathology or solutions might be.

Role modelling to plan for multiple eventualities can be done at all levels. In a single consultation, it could be as simple as asking the patient to return or to seek further help should the problem not be resolved or communicating with a hospital team about the patient so their care is continued. In a clinical setting, it could include how to react to different outcomes from results, not simply assuming that there will be a specific outcome. For example, telling a medical student to take a potassium level for the patient at 10 pm. If the result comes back above the normal range, tell the student to do X. If the result comes back below the normal range tell the student to do Y. If it is normal, tell the student to do Z. If there are other changes, tell the student to call their senior e.t.c. This method expands on expecting a desired result and only telling the student one response.

As described by the educators in chapter 4 (Table 4.5 - *Safe Space*), creating an environment where clinicians can be open and discuss any problems is beneficial to both the clinicians and their patients. This allows students to learn from any potential errors in a psychologically safe way for them and their patients and encourages curiosity over correctness.

6.5 Connections to the existing literature

The foundations of this work were created by many colleagues and academics. I will detail how I have contributed to the body of scientific knowledge in this field. This

work has extended the work of Simpkin et al. on defining types and sources of uncertainty (aleatoric and epistemic) (Simpkin and Armstrong 2019; Gheihman, Johnson, and Simpkin 2020). My research suggests that clinical uncertainty is recognised as being epistemic in type at the start of a medical career and less so with increasing experience. This is perhaps simply the nature of learning. However, this distinction is important as it alters how and who you would teach about clinical uncertainty.

This research has also explored what uncertainty means to medical students. Allied work has been completed by a number of different research groups (Shepherd et al. 2020; Stephens, Sarkar, and Lazarus 2022; Randall and Villareal 2020; Stojan et al. 2022; Stephens, Rees, and Lazarus 2021; Crehan and Scott 2020; Simpkin, Murphy, and Armstrong 2019; Weurlander et al. 2019; Nevalainen, Mantyranta, and Pitkala 2010; Nevalainen et al. 2012; Merrill et al. 1994; Lally and Cantillon 2014; Hancock and Mattick 2020). My research has expanded and added context to much of this work, including variation between different year groups (explored in part by Weissenstein et al. although they found no difference between year groups) and how uncertainty is understood by students in the UK (Weissenstein et al. 2014).

How doctors perceive and manage uncertainty is also a recognised area in the literature (Stojan et al. 2022; Han et al. 2021; Cooke, Doust, and Steele 2013; Lawton et al. 2019). What my research has added to this is how doctors believe they have learned to manage uncertainty. This again is important as it shows that there is no single best way identified as well as reinforcing the importance of being a reflective practitioner and having a psychologically safe environment to work in. There is still some debate as to whether the ability to manage uncertainty is a fixed trait or not (Section 1.3) (Haas and Stojan 2022). My research gives weight to the argument that it is not fixed as many of the participants openly described their own variability in managing clinical uncertainties.

There was agreement by all parties that uncertainty needed to be acknowledged and normalised in practice, rather than hidden or conflated with not knowing. This agrees

with the current discourse about how uncertainty should be taught (Gheihman, Johnson, and Simpkin 2020). Doctors in education wanted students to be comfortable not knowing answers and admitting this even though many students felt that not knowing would lead them to be judged poorly (Table 4.9 - *Yes,* Table 4.13 - *Explicit* and Table 5.3 - *Placement*). The notion of admitting when uncertain was also present in the literature, although I have yet to see an OSCE where uncertainty is rewarded[26] (Randall and Villareal 2020; Danczak and Lea 2014). There may indeed be some disconnect between those interviewed in medical education and those delivering the education.

6.6 Validity and Trustworthiness

In chapter 3 I detailed the recognised validity measures for phenomenographic work (Cope 2004). Below, I have reviewed the original nine measures and described how I have achieved them (Table 6.2). In doing so, I have demonstrated the robustness of the research.

[26] I have been examining OSCEs for 12 years at two different medical schools, and been examined via OSCEs in both undergraduate and postgraduate settings

Table 6.2 - Validity measures for phenomenographic research with the respective evidence

1	The researcher is to state their background - Even though the researcher is approaching the data with an open mind, their experiences will still contribute to their analysis. Acknowledging this allows the reader (and the researcher themself) to be better aware of the context.
	My background, experiences and motivation have been stated in chapter 1.
2	The researcher should state how the sample was chosen and why the purposive sample would be free of bias.
	A purposive sample is unlikely to ever be free of bias. However, a range of both educators and students were invited to contribute, and no participant or data were excluded. All transcripts are available to allow for further scrutiny appendix F.
3	There should be clear justification of the interview schedule.
	The interview schedule was created with the help of the research team and was based on recommendations for the methodology as well as consultation with those more experienced with the methodology (Stenfors-Hayes, Hult, and Dahlgren 2013). The schedule was practised and modified in the two pilot interviews and can be found in appendix B. The topic guide for the medical students was created following this and can be found in appendix C.
4	The details on how data were collected free from bias should be given.
	Details of the data collection were described in chapter three. Only the participants were able to remove data from analysis and the verbatim transcripts can be reviewed in appendix F.
5	The researcher should detail how the data was analysed with an open mind.
	I attempted to remove my prior conceptions through bracketing. I feel that the analysis represents the findings from the data and were regularly surprising. I also repeated the analysis process numerous times to ensure that any relevant data was included.
6	The researcher should give the details of the data analysis process.
	The analysis process was explained with the practical considerations in section 3.2.2. The process was followed for all data.

7	The researcher should ensure that checks and measures are in place to check analysis is appropriate.
	I made sure that I had someone familiar with the methodology as part of my research team, as well as people familiar with qualitative research in general. I held frequent meetings when necessary with the relevant people on the research team to make sure I was performing the research appropriately.
8	Each category of description should include an appropriate quote or quotes.
	I have included at least one relevant quote with each category except for one outcome space (with the exception of Table 4.10 which were examples given by educators, which I felt needed no quotes and can be seen in appendix E).
9	The results should be presented in a fashion which allows for scrutiny by others.
	See appendix F for verbatim transcriptions.

7 - Conclusions

In this final chapter, I have summarised the entirety of the research, discussed the contributions from each of the individual chapters and described how it all fits together. I have explained how the literature search grounded me and demonstrated the limitations in the current interventions; how the medical educators agreed about what uncertainty in medicine was but disagreed as to whether or how it could be taught to medical students; how the medical students desired more teaching, but failed to agree about what medical uncertainty was. I have discussed the limitations of the work, including my thoughts on the methodology and methods employed, considered how this research could be extended, pondered my own impact on the work, reflected on the whole process and finally concluded the research.

7.1 Summary

I started this research by describing myself, what this research would be about and the current literature describing uncertainty and its conceptualisation. I discussed the sources and types of uncertainty relevant to clinical work. I found that uncertainty was challenging for a variety of different reasons, including how it was inconsistently conceptualised, frequently measured and caused a plethora of different emotions, some of which would not be desirable when under duress. I also found that clinical uncertainty was a threshold concept and therefore poorly understood by those who had yet to traverse the threshold and transformative for those who were through it.

In my second chapter, I reviewed the limited number of published interventions that were trying to teach students about how to manage uncertainty. I found a wide variety of interventions, aimed at different year groups within training. The

interventions varied in quality and effectiveness. However, there were some universally applicable learning outcomes from the interventions themselves, which helped guide the final methodology on how to manage medical uncertainty.

In my third chapter, I described my philosophical perspective and how that led me to selecting a relevant methodological approach. I selected a qualitative approach to answer the research questions and phenomenography as my methodology. I then described my methods and how I thought these would best answer my research questions. I chose semi-structured interviews to have meaningful discussions with educators and focus groups for medical students. The methodology was designed to explore critical aspects important in learning about a complex phenomenon and exploring variation in understanding.

Chapter 4 contained the first part of the original research. I interviewed 11 different people, from different institutions around the United Kingdom, all involved with medical education. I analysed their thoughts on the conceptualisation of uncertainty as well as many aspects of teaching, learning and managing uncertainty. Universally, medical educators saw uncertainty as an inherent and manageable part of medical practice. They appeared to have learned how to manage their uncertainty from a mixture of different events throughout the course of their medical career. There were many different views about how and if uncertainty could be taught.

In chapter 5, I asked medical students from the beginning and end of medical school what their thoughts were about uncertainty. What they thought uncertainty was, when they experienced it and how they managed it, were all topics of conversation for the focus groups. Although there was some disagreement, the medical students largely related the uncertainty to themselves, associating it with their own self-worth or prospects within the profession. The ones who had noticed clinical uncertainty wanted more teaching on how best to manage it.

The next chapter synthesised the findings from the two previous chapters, which added complexity to my answers to the research questions. I used my research to

suggest practical recommendations and created some conceptual frameworks around the research subjects.

7.2 Limitations and strengths

I identified a number of limitations and strengths at different stages of the research. I have divided this by chapter starting with the literature review, then the limitations of the interviews and focus groups and finally the methodology.

7.2.1 Literature review

My search strategy for my scoping review was trying to uncover interventions directly linked to teaching uncertainty in healthcare education included the words uncertainty, ambiguity and certainty. Despite the high number of initial papers, very few were relevant and some were excluded even though they seemed initially promising. For example, none of the many papers yielded by the word certainty were included in the final review. Subsequent broadly similar searches with less stringent inclusion criteria, by Moffett et al. and Patel et.al found 58 and 24 papers respectively, in comparison with the eight that I found (Moffett et al. 2021; Patel et al. 2022).

There were a few notable studies excluded. One intervention mainly concerned fully qualified practitioners and used an unclear methodology, consisting of discussing uncertainty with colleagues (Sommers et al. 2007; Kenyon, Allen, and Siegel 2013). This or similar interventions were published multiple times under the name ‘Practice Inquiry’. The intervention was excluded because it was aimed at those past the formative stages of the medical journey and I thought the techniques used would be poorly reproducible. Uncertain trainee General Practitioners in the United Kingdom were also studied in a paper, which asked the question ‘What do you do when you

don’t know what to do?’ (Danczak and Lea 2014). This paper was excluded due to a lack of a formal intervention and as the focus was on researching the General Practitioners rather than how they managed the uncertainty itself.

7.2.2 Interviews with the educators

Potentially, too many areas were explored during the interviews with the educators and this may have made the exploration of each area too superficial. However, as the methodology allowed for participant interpretation of the questions, different educators could focus on different areas. Thus every participant had an opportunity to answer each question as fully as they liked and as the data were analysed in a group format (a prerequisite of the methodology) and therefore no area of questioning appeared underrepresented during the analysis.

There were practical limitations about who could be interviewed. Personal connections, obtained through recommendations from the supervisory group, were more willing to be interviewed than those emailed cold. The methodology required purposeful sampling and to stop sampling when data redundancy occurred (Marton and Pong 2005). When I found that categories were repeating, in consultation with my supervisory team, I stopped attempting to find new people to interview. Practical considerations concerning data management including deliberately restricting the number of interviews had been suggested by others using the methodology (Trem 2017; Trigwell 2000).

> “Researchers will use experience and judgement to determine when to stop data collection, and the amount of data collected for analysis is a practical consideration that must be included in this judgement.” - (Trem 2017, 2)

The validity of qualitative work continues to be questioned by the academic community (Low 2019; Braun and Clarke 2021). However closely the methodology is

followed, the concept of ‘enough data’ will always be subjective, especially when working alone.

7.2.3 Focus groups with the medical students

For pragmatic reasons I only used medical students from a single medical school. However, as the medical school is currently accredited by the GMC and subjected to periodic reviews, the experiences that occur at BSMS are plausibly representative of and relevant to all medical students. If the resources were available, I would have included participants from other medical schools, especially those with different curriculum formats. Speaking to more students might have revealed how uncertainty was approached elsewhere as well as add more bredth to the findings. I also would have included the thoughts of patient participation groups who often can add differing unconsidered perspectives.

The amount of time spent interviewing was shorter than with the medical educators. A total of around four hours was spent, leading to the collection of less data, even though there were 11 participants in both cohorts (educators and students). All students who responded to the invitation were invited to be interviewed. Less data meant there were overall fewer conceptions for each category although the categories were starting to repeat both within and between the focus groups. It is not possible to judge how different the data would have been if each student had been interviewed individually.

The focus groups seemed like an appropriate way for the students to participate, leading to wider variations in response. However, it did also lead to many side tracks, where other elements (complaints about the state of medical education, potential alternative careers) were discussed until a point where I could lead the participants back to a relevant area.

I was concerned that the seniority difference between me and the students might limit how open the students might be but they appeared to open up and share their

vulnerabilities with the group and me. Once I had stopped recording, there was a sense of relief from many of the students who said they had enjoyed the session as they had felt they had been the only ones to suffer from uncertainty.

7.2.4 Methodology

Some limitations with the methodology have been described in the literature including: what is data; how to truly bracket oneself from the data; the suggestion that categories and hierarchies are forced; as well as the fact that the analysis adds legitimacy and equal value to all comments made (Cibangu and Hepworth 2016; Ashworth and Lucas 1998). Adding equal value to all comments undermines one of the main strengths of qualitative research – the ability to explore narrative or individual experiences. As the phenomenographic methodology combines all data, an individual's narrative is lost in favour of observing variation and group meanings. While this is a useful outcome, especially when exploring new phenomena, this feels like a lengthy way of achieving it.

Finally, I was unable to create a hierarchy from some of the data. I discussed this issue with my research team and at a breakout room of a conference of international phenomenographic research (Bergmar 2022). It was suggested that I re-review my data but that a hierarchy may not always be possible. This could be due to the nature of some questions or the style of data collection and analysis. Questions such as the opening question about conceptions of uncertainty, when participants were encouraged to expand on what they had said, were perhaps too broad. While for the focus groups, limiting the amount of time each participant spoke meant that most felt restricted by time or the pressure of others wanting to speak. This was highlighted by the fact that the interview with only two students took the same amount of time as the one with 5 students.

7.3 Areas for future research

There are opportunities to expand on my research. One area includes creating relevant targeted interventions and integrating them into curricula incorporating my proposed methodology for managing uncertainty (Section 6.4). Another is understanding what makes a useful enjoyable intervention rather than simply box-ticking, which was a concern of the students.

For example, randomness, an aspect of aleatoric uncertainty, is an area that has been studied and utilised heavily in successful game design. Brown, in a YouTube talk (viewed over 2.6 million times), describes the necessity of randomness in games to provide variety and unpredictability for problems (M. Brown 2020). Incorporating randomness into problems allows players to master the skills required rather than just memorising the specific correct response.

The clinical psychologist and expert in uncertainty Professor Mark Freeston suggested that games were a novel way to help students make a transformation from viewing uncertainty as a threat and instead seeing it as something enjoyable (Freeston 2022). He effectively wanted to turn problematic (epistemic) uncertainty into manageable (aleatoric) uncertainty.

Incorporating an element of randomness into clinical teaching has the potential to allow students to experience uncertainty directly. This is surely what we as educators want when setting practical medical exams and would be an interesting next stage of this research.

Another potential avenue for further research involves the inclusion of summative or formative testing about the management of a clinical situation when uncertain. This certainly would be a more obvious way to demonstrate the achievement from Outcomes for Graduates (GMC 2018). However, the addition of, for example, an uncertainty-related OSCE station in an exam might be conceptually problematic for the students. The student might question their uncertainty and might not apply the relevant skills to the station, or the reverse and apply their uncertainty management skills to another station where the uncertainty was caused by inappropriate actions. Other types of assessments may be more appropriate, such as longer examinations

or simulations. Clearly, more research is needed in this area to ensure that any uncertainty assessment is genuinely beneficial to students.

7.4 Reflexivity and reflection

7.4.1 Reflexivity

Reflexivity is an act, by the researcher, of considering how they as an individual impacted the research (Reid et al. 2018). This included considering my biases and how these might have changed the outcomes of the research with the potential to 'force data' (Glaser 1992). I have considered these in the context of:

- The way I collected my data
- How I analysed the data
- How I reported the data

The biggest impact I could have had on the data was in the choice of who to interview. Especially with purposive samples, I could have selected a sample that reflected my own initial beliefs, if that was my desired purpose. I understand that by not including any socio-demographic this claim is open to scrutiny as there is the potential to exclude specific demographics. Collecting this data could have allowed for the identification of specific trends or the observation that various demographics had been excluded. I will address this by confirming that I went into this research with an open mind and although I selected who to invite to interview, this was based on the recommendations of the research group or others in medical education and I did not exclude any willing participant. The medical students were a self-selecting group, from the cohorts who were emailed (the entire year 1 and years 4 and 5 were emailed). No student was excluded unless they failed to meet the inclusion criteria. The inclusion criteria were well justified in the chapter.

I analysed the data using the methodology I described in chapter 3. I attended appropriate training, regular supervision from the research team, as well as reaching out to others in the methodological field and the practice interviews greatly helped with my confidence in how best to get an appropriately detailed response from a

participant. I attempted to be consistent in this approach and I reviewed the transcripts multiple times both before and after I selected what was data. The semi-structured approach made the interviews flow and people willingly opened up about their emotional responses to uncertainty. I attempted to include data that surprised me as well as responses that I had heard before including data that contradicted other data. My interview schedule, following numerous iterations, was written in a way that minimised my biases. My data analysis was reviewed by the research team a number of times and the recommendations made by the team were followed. I followed the methods described to ensure that my findings would be considered valid and have not censored any of the data collected (Appendix F). I accept that I have used my own values and experiences when constructing many of the hierarchies, especially when constructing the ones that were inclusive. I believe I have been transparent whilst doing this, I have stated what sort of hierarchies they are and why, and that the logical connections between the levels are visible to others.

Being reflexive is an extremely important aspect of qualitative research. It is possible that a different researcher would have approached the research topic differently, but hopefully would have arrived at similar conclusions based on the data collected.

7.4.2 Personal reflection

In this section I will consider the actions I have taken. This has been a long journey full of discovery and frameshift changes in my perspective, with considerably more philosophy than expected.

My literature review strategy could have been improved. The review was aimed at discovering and analysing the current interventions aimed at teaching healthcare students how to manage uncertainty. At the time, I had felt that a systematic review might have been the most appropriate search, however, the scoping review of the area yielded more relevant results as demonstrated and following my review, two

subsequent reviews were published (Patel et al. 2022; Moffett et al. 2021). The fact that there have been two similar scoping reviews published so close together demonstrated the current interest in the area of uncertainty. I had not appreciated what information I required at the start of the research and had tried to answer my research questions before fully grasping the information needed. However, in light of the subsequent reviews, I felt it was not necessary to revise the search.

Selecting an appropriate methodology appeared to be at the heart of qualitative research. I found it difficult to consider what my research paradigm was from the very limited understanding of the pros and cons of each available. Phenomenography seemed to stand out to me as being appropriate, being aimed at education research, and being quite intuitive, with the main drawback being that there was initially no local support available. Thankfully the phenomenographic community was very receptive to questions, often answering emails within hours of them being sent and I gladly accepted Dr Clare Forder onto the research team. As any methodology would have been new to me, I saw learning how to do phenomenography as challenging as learning any other potential methodology.

The interviews and focus groups were very enjoyable and a highlight of the research process. It was genuinely a privilege to speak to so many highly intelligent people and hear their opinions, and I was relieved to hear them talk with enthusiasm about a subject that I was interested in and say things that were both unexpected and different from each other. This made bracketing my preconceptions very straightforward and participant enthusiasm meant that I rarely had to intervene or continually ask for further examples. The earlier interviews, which tended to be with people I knew better, allowed me to practise a very relaxed style, which I felt helped with the later ones.

I struggled initially with the analysis phase of the research process. I now understand it was partially my lack of experience, but also the type of question I asked. This meant I was unable to form hierarchies for outcome spaces for all areas. Those with outcome spaces that were harder to derive were:

How did educators conceptualise uncertainty?

When do students experience uncertainty?

Where does uncertainty in medicine fit in medical education?

These questions were largely hypothetical or called upon multiple experiences. The methodology I used, which is aimed at analysing second-order experiences, meant I derived a less clear outcome space when answering questions not related to experiences[27]. The other questions I felt better suited the methodology and the analysis was more straightforward. Doing the analysis as part of a team would go further to reduce the impact of a single researcher, however, this would have been impractical for this PhD (Rands and Gansemer-Topf 2016).

The methodology was not flawless. Subtleties, such as individual narratives and contradictions arching across a single interview, were lost when the data were combined. I had also originally intended to combine the findings from the medical students and educators. However, due to the disparity in the amount of data, and the variation in the way the questions were asked, I was concerned that the essence of the students would be lost or the overall findings would not be meaningful.

Finally, I found writing in the first person both relevant and enriching. I originally wrote the whole body of work in the third person, but this felt unnatural as I referred to choices that I had made in the third person and attempted to disregard my interpretation of the data. Learning that I am a part of my research arrived with a greater understanding of my own onto-epistemological insights of the world.

[27] Phenomenography has previously been used for hypothetical or opinion-based questions (Hajar 2021)

7.5 Conclusions

Uncertainty, as a phenomenon, is difficult to learn about because it is personal, always relevant and normally managed fluently by experienced practitioners. Communicating and managing uncertainty is a part of Gestalt medical practice, and is another threshold that medical students need to transcend on their journey to becoming functioning junior doctors. Uncertainty cannot be avoided and there is no place in medicine where a doctor can hide from it. Negative emotional reactions towards uncertainty are common in both medical students and junior doctors, likely due to a lack of awareness of its normality, and therefore the area warrants continued research interest.

As most educators felt that they learned to manage their uncertainty through time and clinical experience, attempting to teach a methodology to manage uncertainty might be lost on those who are not frequently taking clinical actions and just want to acquire more knowledge. This must be weighed against both the students' expressions of interest to have some form of teaching on the phenomenon as well as the higher curriculum setters creating competencies based on managing uncertainty. A balance should be struck and current postgraduate models, especially small group teaching and self-reflection, could be implemented. It was best put by a year 4 student in the first focus group discussion:

> *"I don't know if you can teach uncertainty. You can definitely talk about it."* - T

Teaching about uncertainty is complicated because it is a threshold concept. This means that those who have transitioned and fully accepted uncertainty might not be aware of how those who are yet to make this transition feel about the phenomenon. This finding was repeated numerous times in my research with educators describing management related to aleatoric uncertainty, whilst medical students only really described epistemic uncertainty. Understanding this impacts the placement and type of any teaching intervention.

There have been many quotes that people have sent me when they discovered I was writing about uncertainty. I have finished this work with one that is as relevant now as it was when it was written.

> Doubt is not a pleasant condition, but certainty is an absurd one. - Voltaire (1767)

References

Abrandt, Madeleine. 1997. *Learning Physiotherapy: The Impact of Formal Education and Professional Experience*. Linköping University, Department of Education and Psychology.

Adams, Douglas. 1981. *The Hitchhiker's Guide to the Galaxy*. Pocket Books.

Ahmed, Amira, Frances Johnson, Geoff Walton, and Sumayah Bayounis. 2020. "A Phenomenographic Approach to the Effect of Emotions on the Information Behaviour of Doctoral Students: A Narrative Inquiry." In *Sustainable Digital Communities*, 874–83. Springer International Publishing.

Åkerlind. 2005. "Variation and Commonality in Phenomenographic Research Methods." *Higher Education Research & Development*. https://www.tandfonline.com/doi/abs/10.1080/07294360500284672?casa_token=QWUZMW_CNtAAAAAA:sLXaIFQXRgDGWOAkI2e-KZsnKHURR988JUN1dKiLBvpmb2OkQY7yWRIcMjQKX13izrPNwMeH95xiPA.

———. 2008. "A Phenomenographic Approach to Developing Academics' Understanding of the Nature of Teaching and Learning." *Teaching in Higher Education*. https://doi.org/10.1080/13562510802452350.

———. 2015. "From Phenomenography to Variation Theory: A Review of the Development of the Variation Theory of Learning and Implications for Pedagogical Design in Higher Education." *HERDSA Review of Higher Education* 2: 5–26.

———. 2018. "What Future for Phenomenographic Research? On Continuity and Development in the Phenomenography and Variation Theory Research Tradition." *Scandinavian Journal of Educational Research* 62 (6): 949–58.

Akerlind, Gerlese, John Bowden, and Pam Green. 2005. "Learning to Do Phenomenography: A Reflective Discussion." In *Doing Developmental Phenomenography*, 74–100. RMIT Press.

Alsop, Graham, and Chris Tompsett. 2006. "Making Sense of 'pure' Phenomenography in Information and Communication Technology in Education." *Research in Learning Technology*. https://doi.org/10.3402/rlt.v14i3.10966.

Anderson, Eric C., R. Nicholas Carleton, Michael Diefenbach, and Paul K. J. Han. 2019. "The Relationship Between Uncertainty and Affect." *Frontiers in Psychology* 10 (November): 2504.

Ashworth, Peter, and Ursula Lucas. 1998. "What Is the 'world' of Phenomenography?" *Scandinavian Journal of Educational Research* 42 (4): 415–31.

———. 2000. "Achieving Empathy and Engagement: A Practical Approach to the Design, Conduct and Reporting of Phenomenographic Research." *Studies in Higher Education* 25 (3): 295–308.

Babrow, A. S., C. R. Kasch, and L. A. Ford. 1998. "The Many Meanings of Uncertainty in Illness: Toward a Systematic Accounting." *Health Communication* 10 (1): 1–23.

Badyal, Dinesh K., and Tejinder Singh. 2017. “Learning Theories: The Basics to Learn in Medical Education.” *International Journal of Applied & Basic Medical Research* 7 (Suppl 1): S1–3.
Barnard, A., H. McCosker, and R. Gerber. 1999. “Phenomenography: A Qualitative Research Approach for Exploring Understanding in Health Care.” *Qualitative Health Research* 9 (2): 212–26.
Barnett-Page, Elaine, and James Thomas. 2009. “Methods for the Synthesis of Qualitative Research: A Critical Review.” *BMC Medical Research Methodology* 9 (August): 59.
Barnett, Ronald. 2012. “Learning for an Unknown Future.” *Higher Education Research & Development* 31 (1): 65–77.
Barr, Donald A. 2010. “Science as Superstition: Selecting Medical Students.” *The Lancet* 376 (9742): 678–79.
Bentwich, Miriam Ethel, and Peter Gilbey. 2017. “More than Visual Literacy: Art and the Enhancement of Tolerance for Ambiguity and Empathy.” *BMC Medical Education* 17 (1): 200.
Beresford, E. B. 1991. “Uncertainty and the Shaping of Medical Decisions.” *The Hastings Center Report* 21 (4): 6–11.
Bergmar, Hilda. 2022. “EARLI SIG 9 Conference 2022: Phenomenography and Variation Theory in Practice - Department of Teaching and Learning.” 2022. https://www.su.se/department-of-teaching-and-learning/research/conferences-and-seminars/earli-sig-9-conference-2022-phenomenography-and-variation-theory-in-practice-1.610226?open-collapse-boxes=ccbd-generalprogram,ccbd-findyourway,ccbd-registrationandfees,ccbd-bookofabstracts.
Bhat, Chirag, Sarah Burm, Tricia Mohan, Saad Chahine, and Mark Goldszmidt. 2018. “What Trainees Grapple with: A Study of Threshold Concepts on the Medicine Ward.” *Medical Education* 52 (6): 620–31.
Bhise, Viraj, Suja S. Rajan, Dean F. Sittig, Robert O. Morgan, Pooja Chaudhary, and Hardeep Singh. 2018. “Defining and Measuring Diagnostic Uncertainty in Medicine: A Systematic Review.” *Journal of General Internal Medicine* 33 (1): 103–15.
Booth. 1997. “On Phenomenography, Learning and Teaching.” *Higher Education Research & Development* 16 (2): 135–58.
Booth, Shirley A. 1998. “Learning to Program: A Phenomenographic Perspective.” https://elibrary.ru/item.asp?id=6876573.
Borracci, Raúl A., Graciana Ciambrone, and Eduardo B. Arribalzaga. 2021. “Tolerance for Uncertainty, Personality Traits and Specialty Choice Among Medical Students.” *Journal of Surgical Education* 78 (6): 1885–95.
Bowden, and Green. 2005. “Doing Developmental Phenomenography.” *Doing Developmental Phenomenography*, vi.
Bowden, John. 2005. “Reflections on the Phenomenographic Team Research Process.” *Doing Developmental Phenomenography* 11. https://researchbank.swinburne.edu.au/items/53ede876-42a9-462e-9ab0-1376de63bfe7/1/PDF%20%28Published%20version%29.pdf.
Braun, Virginia, and Victoria Clarke. 2006. “Using Thematic Analysis in Psychology.” *Qualitative Research in Psychology* 3 (2): 77–101.
———. 2021. “To Saturate or Not to Saturate? Questioning Data Saturation as a Useful Concept for Thematic Analysis and Sample-Size Rationales.” *Qualitative Research in Sport, Exercise and Health* 13 (2): 201–16.
Brown, Brené. 2021. *Atlas of the Heart: Mapping Meaningful Connection and the Language of Human Experience*. Random House.
Brown, and Angelique N. Dueñas. 2020. “A Medical Science Educator’s Guide to Selecting a Research Paradigm: Building a Basis for Better Research.” *Medical Science Educator* 30 (1): 545–53.
Brown, Mark. 2020. “The Two Types of Random in Game Design.” Youtube. January 14, 2020. https://www.youtube.com/watch?v=dwI5b-wRLic.
Bruce, Christine. 1997. “The Seven Faces of Information Literacy.”

https://www.bestlibrary.org/digital/files/bruce.pdf.
Budner, S. 1962. “Intolerance of Ambiguity as a Personality Variable.” *Journal of Personality* 30 (March): 29–50.
Bunniss, Suzanne, and Diane R. Kelly. 2010. “Research Paradigms in Medical Education Research.” *Medical Education* 44 (4): 358–66.
Bussey, Thomas J., Marykay Orgill, and Kent J. Crippen. 2013. “Variation Theory: A Theory of Learning and a Useful Theoretical Framework for Chemical Education Research.” *Chemistry Education Research and Practice* 14 (1): 9–22.
Bynum, William E., 4th, and Jeffrey L. Goodie. 2014. “Shame, Guilt, and the Medical Learner: Ignored Connections and Why We Should Care.” *Medical Education* 48 (11): 1045–54.
Bynum, William E., 4th, Lara Varpio, Janaka Lagoo, and Pim W. Teunissen. 2021. “‘I’m Unworthy of Being in This Space’: The Origins of Shame in Medical Students.” *Medical Education* 55 (2): 185–97.
Byrne, Alex, and David R. Hilbert. 2003. “Color Realism and Color Science.” *The Behavioral and Brain Sciences* 26 (1): 3–21; discussion 22–63.
Cibangu, Sylvain K., and Mark Hepworth. 2016. “The Uses of Phenomenology and Phenomenography: A Critical Review.” *Library & Information Science Research* 38 (2): 148–60.
Cleary, Michelle, Jan Horsfall, and Mark Hayter. 2014. “Data Collection and Sampling in Qualitative Research: Does Size Matter?” *Journal of Advanced Nursing* 70 (3): 473–75.
Collett, T., H. Neve, and N. Steven. 2017. “Using Audio Diaries to Identify Threshold Concepts in ‘Softer’ Disciplines: A Focus on Medical Education,” April. https://pearl.plymouth.ac.uk/handle/10026.1/9283.
Cook, Chad. 2009. “Is Clinical Gestalt Good Enough?” *The Journal of Manual & Manipulative Therapy* 17 (1): 6–7.
Cooke, Georga P. E., Jenny A. Doust, and Michael C. Steele. 2013. “A Survey of Resilience, Burnout, and Tolerance of Uncertainty in Australian General Practice Registrars.” *BMC Medical Education* 13 (January): 2.
Cope. 2004. “Ensuring Validity and Reliability in Phenomenographic Research Using the Analytical Framework of a Structure of Awareness.” *Qualitative Research Journal*. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.93.8535&rep=rep1&type=pdf#page=4.
Cope, Horan, and Garner. 1998. “Conceptions of an Information System and Their Use in Teaching about IS.” *Informing Sci. Int. J. an Emerg. Transdiscipl.* 1: 9–22.
Cossham, Amanda F. 2017. “An Evaluation of Phenomenography.” *Library and Information Research* 41 (125): 17–31.
Crehan, Emily, and Aneya Scott. 2020. “Balint Groups as a Proposed Support Mechanism to Reduce Uncertainty in Medical Students.” *Medical Education*.
Custers, Eugéne J. F. M., Henny P. A. Boshuizen, and Henk G. Schmidt. 1998. “The Role of Illness Scripts in the Development of Medical Diagnostic Expertise: Results From an Interview Study.” *Cognition and Instruction* 16 (4): 367–98.
Dahlgren. 1976. *Investigations Into the Learning and Teaching of Basic Concepts in Economics: A Research Project on Higher Education*. Pedagogiska institutionen, Göteborgs univ.
Dahlgren, Lars-Ove, and M. Fallsberg. 1991. “Phenomenography as a Qualitative Approach in Social Pharmacy Research.” *Journal of Social and Administrative Pharmacy: JSAP* 8 (4): 150–56.
Danczak, Avril, and Alison Lea. 2014. “What Do You Do When You Don’t Know What to Do? GP Associates in Training (AiT) and Their Experiences of Uncertainty.” *Education for Primary Care*. https://doi.org/10.1080/14739879.2014.11730762.
Danczak, Avril, Alison Lea, and Geraldine Murphy. 2016. *Mapping Uncertainty in Medicne: What to Do When You Don’t Know What to Do?* Royal College of General Practitioners.
Daniel, Mann, and Mazzolini. 2016. “A Phenomenography of Lecturing.” In . https://www.academia.edu/download/49089247/Daniel-A_phenomenography_of_lecturing-

56_a.pdf.
Dixon-Woods, Mary, Debbie Cavers, Shona Agarwal, Ellen Annandale, Antony Arthur, Janet Harvey, Ron Hsu, et al. 2006. “Conducting a Critical Interpretive Synthesis of the Literature on Access to Healthcare by Vulnerable Groups.” *BMC Medical Research Methodology* 6 (July): 35.
Dortins, Emma. 2002. “Reflections on Phenomenographic Process: Interview, Transcription and Analysis.” *Quality Conversations: Research and Development in Higher Education* 25: 207–13.
El-Haddad, Carlos, Iman Hegazi, and Wendy Hu. 2020. “Understanding Patient Expectations of Health Care: A Qualitative Study.” *Journal of Patient Experience* 7 (6): 1724–31.
Englund, Claire, Anders D. Olofsson, and Linda Price. 2017. “Teaching with Technology in Higher Education: Understanding Conceptual Change and Development in Practice.” *Higher Education Research & Development* 36 (1): 73–87.
Entwistle, Noel. 1997. “Introduction: Phenomenography in Higher Education.” *Higher Education Research & Development* 16 (2): 127–34.
Etikan, Musa, and Alkassim. 2016. “Comparison of Convenience Sampling and Purposive Sampling.” *American Journal of Theoretical and Applied Business*. https://www.academia.edu/download/55796997/Comparison_Convenience_and_Purposive_Sampling-2016_4p.pdf.
“Etymonline - Online Etymology Dictionary.” 2022. May 27, 2022. https://www.etymonline.com/.
Fenwick, Tara, and Richard Edwards. 2010. *Actor-Network Theory in Education*. Routledge.
Fernandez, Nicolas, Amélie Foucault, Serge Dubé, Diane Robert, Chantal Lafond, Anne-Marie Vincent, Jeannine Kassis, Driss Kazitani, and Bernard Charlin. 2016. “Learning-by-Concordance (LbC): Introducing Undergraduate Students to the Complexity and Uncertainty of Clinical Practice.” *Canadian Medical Education Journal* 7 (2): e104–13.
Ferrier, James Frederick. 1856. *Institutes of Metaphysic: The Theory of Knowing and Being*. W. Blackwood and sons.
Fins, Joseph J., Matthew D. Bacchetta, and Franklin G. Miller. 1997. “Clinical Pragmatism: A Method of Moral Problem Solving.” *Kennedy Institute of Ethics Journal* 7 (2): 129–45.
Francis, Hazel. 1993. “Advancing Phenomenography: Questions of Method.” *Nordisk Pedagogik* 13 (2): 68–75.
Fraser, S. W., and T. Greenhalgh. 2001. “Coping with Complexity: Educating for Capability.” *BMJ* 323 (7316): 799–803.
Freeston. 2022. “Owning Uncertainty about Intolerance of Uncertainty.” September 2.
Freeston, Josée Rhéaume, Hélène Letarte, Michel J. Dugas, and Robert Ladouceur. 1994. “Why Do People Worry?” *Personality and Individual Differences*. https://doi.org/10.1016/0191-8869(94)90048-5.
Freilich, Joel, Eivor Wiking, Gunnar H. Nilsson, and Christina Olsson. 2019. “Patients’ Ideas, Concerns, Expectations and Satisfaction in Primary Health Care – a Questionnaire Study of Patients and Health Care Professionals’ Perspectives.” *Scandinavian Journal of Primary Health Care*. https://doi.org/10.1080/02813432.2019.1684430.
Gaulin, Mathieu O., and Caroline G. L. Cao. 2005. “Surgical Learning Aid: Reducing Uncertainty for the Novice during Simulated Minimally Invasive Surgery.” *PsycEXTRA Dataset*. https://doi.org/10.1037/e577352012-030.
Gaunt, Trevor, and Claire Loffman. 2018. “When I Say… Threshold Concepts.” *Medical Education* 52 (8): 789–90.
Geller, G., R. R. Faden, and D. M. Levine. 1990. “Tolerance for Ambiguity among Medical Students: Implications for Their Selection, Training and Practice.” *Social Science & Medicine* 31 (5): 619–24.
Geller, G., E. S. Tambor, G. A. Chase, and N. A. Holtzman. 1993. “Measuring Physicians’ Tolerance for Ambiguity and Its Relationship to Their Reported Practices Regarding Genetic Testing.” *Medical Care* 31 (11): 989–1001.
General Medical Council. 2018. “Outcomes for Graduates.” 2018. https://www.gmc-uk.org/-

/media/documents/outcomes-for-graduates-a4-6_pdf-78952372.pdf.
Gerrity, R. F. DeVellis, and J. A. Earp. 1990. “Physicians’ Reactions to Uncertainty in Patient Care. A New Measure and New Insights.” *Medical Care* 28 (8): 724–36.
Gerrity, Martha S., Robert F. DeVellis, and Donald W. Light. 1992. “Uncertainty and Professional Work: Perceptions of Physicians in Clinical Practice.” *The American Journal of Sociology* 97 (4): 1022–51.
Gheasuddin, Annie Noor, Rohan Misra, and Jayden Patel. 2021. “Use of an Apprenticeship Model to Facilitate Prescribing Learning on Clinical Placements.” *Medical Teacher*, September, 1.
Gheihman, Galina, Mark Johnson, and Arabella L. Simpkin. 2020. “Twelve Tips for Thriving in the Face of Clinical Uncertainty.” *Medical Teacher* 42 (5): 493–99.
Glaser, Barney G. 1992. *Basics of Grounded Theory Analysis: Emergence Vs Forcing*. Sociology Press.
GMC. 2018. “Outcomes for Graduates.” General Medical Council London, UK. 2018. https://www.gmc-uk.org/education/standards-guidance-and-curricula/standards-and-outcomes/outcomes-for-graduates/outcomes-for-graduates.
Golden, William Christopher, Silka C. Patel, Betty Chou, Robert Arthur Dudas, Rosalyn Walker Stewart, Eric D. Balighian, Salwa Khan, Nancy A. Hueppchen, and Michael A. Barone. 2018. “Development and Evaluation of a Simulation-Based, Medical Student Teaching Session for Communicating Bad News and Uncertainty Along the Obstetric-Neonatal Continuum.” *Medical Science Educator*. https://doi.org/10.1007/s40670-017-0493-2.
Goldie, John. 2012. “The Formation of Professional Identity in Medical Students: Considerations for Educators.” *Medical Teacher* 34 (9): e641–48.
“Google Sheets.” 2022. February 14, 2022. https://www.google.co.uk/sheets/about/.
Gordon, Sue, and Jackie Nicholas. 2015. “What Do Bridging Students Understand by ‘assumed Knowledge’in Mathematics?” *International Journal of Innovation in Science and Mathematics Education* 23 (1). https://openjournals.library.usyd.edu.au/index.php/CAL/article/view/8486.
Greenmyer, Jacob R., Michelle Montgomery, Charles Hosford, Michael Burd, Vanessa Miller, Michael H. Storandt, Koffi L. Lakpa, and Christopher Tiongson. 2022. “Guilt and Burnout in Medical Students.” *Teaching and Learning in Medicine* 34 (1): 69–77.
Grote, Helen, Mazn Raouf, and Caroline Elton. 2012. “Developing Career Resilience in Medicine.” *BMJ* 344 (May). https://doi.org/10.1136/bmj.e3106.
Grupe, Dan W., and Jack B. Nitschke. 2013. “Uncertainty and Anticipation in Anxiety: An Integrated Neurobiological and Psychological Perspective.” *Nature Reviews. Neuroscience* 14 (7): 488–501.
Haas, Mary, and Jennifer Nicole Stojan. 2022. “Uncertainty about Uncertainty Tolerance: The Elephants in the Room.” *Medical Education*.
Hajar, Anas. 2021. “Theoretical Foundations of Phenomenography: A Critical Review.” *Higher Education Research & Development*. https://doi.org/10.1080/07294360.2020.1833844.
Hale, Andrew J., Daniel N. Ricotta, Jason Freed, C. Christopher Smith, and Grace C. Huang. 2019. “Adapting Maslow’s Hierarchy of Needs as a Framework for Resident Wellness.” *Teaching and Learning in Medicine* 31 (1): 109–18.
Hammond, Jennifer A., Jason Hancock, Margaret S. Martin, Susan Jamieson, and Dominic J. Mellor. 2017. “Development of a New Scale to Measure Ambiguity Tolerance in Veterinary Students.” *Journal of Veterinary Medical Education* 44 (1): 38–49.
Hampton, J. R., M. J. Harrison, J. R. Mitchell, J. S. Prichard, and C. Seymour. 1975. “Relative Contributions of History-Taking, Physical Examination, and Laboratory Investigation to Diagnosis and Management of Medical Outpatients.” *British Medical Journal* 2 (5969): 486–89.
Han. 2021. *Uncertainty in Medicine: A Framework for Tolerance*. Oxford University Press.
Hancock, Jason, Jennifer A. Hammond, Martin Roberts, and Karen Mattick. 2017. “Comparing Tolerance of Ambiguity in Veterinary and Medical Students.” *Journal of Veterinary Medical Education* 44 (3): 523–30.
Hancock, Jason, and Karen Mattick. 2012. “Increasing Students’ Tolerance of Ambiguity: The Need for Caution.” *Academic Medicine: Journal of the Association of American Medical Colleges*.

———. 2020. “Tolerance of Ambiguity and Psychological Well-Being in Medical Training: A Systematic Review.” *Medical Education* 54 (2): 125–37.
Hancock, Jason, Martin Roberts, Lynn Monrouxe, and Karen Mattick. 2015. “Medical Student and Junior Doctors’ Tolerance of Ambiguity: Development of a New Scale.” *Advances in Health Sciences Education: Theory and Practice* 20 (1): 113–30.
———. 2016. “Tolerance of Ambiguity in Medical Students and Doctors Scale.” *PsycTESTS Dataset*. https://doi.org/10.1037/t45944-000.
Han, and Robert A. Ellis. 2019. “Using Phenomenography to Tackle Key Challenges in Science Education.” *Frontiers in Psychology* 10 (June): 1414.
Han, William M. P. Klein, and Neeraj K. Arora. 2011. “Varieties of Uncertainty in Health Care: A Conceptual Taxonomy.” *Medical Decision Making: An International Journal of the Society for Medical Decision Making* 31 (6): 828–38.
Han, Paul K. J., Tania D. Strout, Caitlin Gutheil, Carl Germann, Brian King, Eirik Ofstad, Pål Gulbrandsen, and Robert Trowbridge. 2021. “How Physicians Manage Medical Uncertainty: A Qualitative Study and Conceptual Taxonomy.” *Medical Decision Making: An International Journal of the Society for Medical Decision Making* 41 (3): 275–91.
Harden, R. M. 1999. “What Is a Spiral Curriculum?” *Medical Teacher* 21 (2): 141–43.
Harsh, Suri. 2011. “Purposeful Sampling in Qualitative Research Synthesis.” *Qualitative Research Journal* 11 (2): 63–75.
Hasselgren, Biörn, and Dennis Beach. 1997. “Phenomenography — a ‘good-for-nothing Brother’ of Phenomenology? Outline of an Analysis.” *Higher Education Research & Development* 16 (2): 191–202.
Hillen, Marij A., Caitlin M. Gutheil, Tania D. Strout, Ellen M. A. Smets, and Paul K. J. Han. 2017. “Tolerance of Uncertainty: Conceptual Analysis, Integrative Model, and Implications for Healthcare.” *Social Science & Medicine* 180 (May): 62–75.
Hong, Quan Nha, Sergi Fàbregues, Gillian Bartlett, Felicity Boardman, Margaret Cargo, Pierre Dagenais, Marie-Pierre Gagnon, et al. 2018. “The Mixed Methods Appraisal Tool (MMAT) Version 2018 for Information Professionals and Researchers.” *Education for Information*. https://doi.org/10.3233/efi-180221.
Horsburgh, Jo, and Kate Ippolito. 2018. “A Skill to Be Worked at: Using Social Learning Theory to Explore the Process of Learning from Role Models in Clinical Settings.” *BMC Medical Education* 18 (1): 156.
Ilgen, Jonathan S., Kevin W. Eva, Anique de Bruin, David A. Cook, and Glenn Regehr. 2019. “Comfort with Uncertainty: Reframing Our Conceptions of How Clinicians Navigate Complex Clinical Situations.” *Advances in Health Sciences Education: Theory and Practice* 24 (4): 797–809.
Ilgen, Jonathan S., Bjorn K. Watsjold, and Glenn Regehr. 2022. “Is Uncertainty Tolerance an Epiphenomenon?” *Medical Education*.
Ingram, Shirley. 2017. “Taking a Comprehensive Health History: Learning through Practice and Reflection.” *The British Journal of Nursing* 26 (18): 1033–37.
Jenkins, C. S. 2010. “What Is Ontological Realism?” *Philosophy Compass* 5 (10): 880–90.
Jennifer, M., J. M. Case, and G. Light. 2011. “Emerging Methodologies in Engineering Education Research.” *Journal of Engineering Education* 100 (1): 186–210.
Johansson, B., F. Marton, and L. Svensson. 1985. “An Approach to Describing Learning as Change between Qualitatively Different Conceptions. Cognitive Structure and Conceptual Change. A. Pines & T. West, Eds.” New York, Academic Press.
Jones, Daniel, Laurie Dunn, Ian Watt, and Una Macleod. 2019. “Safety Netting for Primary Care: Evidence from a Literature Review.” *The British Journal of General Practice: The Journal of the Royal College of General Practitioners* 69 (678): e70–79.
Jones, Helen, and Lucy Hammond. 2022. “Threshold Concepts in Medical Education: A Scoping Review.” *Medical Education* 56 (10): 983–93.
Jupp, Victor. 2006. “QSR NVIVO.” Http://methods.sagepub.com/reference/the-Sage-Dictionary-of-

Social-Research-methods/n163.xml. 2006. https://doi.org/10.4135/9780857020116.n163.
Kelly, Michaela, Johanna Lynch, Penny Mainstone, Alison Green, and Nancy Sturman. 2022. "'Things We Are Expected to Just Do and Deal With': Using the Medical Humanities to Encourage Reflection on Vulnerability and Nurture Clinical Skills, Collegiality, Compassion, and Self-Care." *Perspectives on Medical Education*. https://doi.org/10.1007/s40037-022-00724-w.
Kenyon, Tina, Claudia W. Allen, and Alan Siegel. 2013. "Using Practice Inquiry to Engage Uncertainty in Residency Education." *Clinical Uncertainty in Primary Care*. https://doi.org/10.1007/978-1-4614-6812-7_10.
Khan, Shahadat Hossain. 2014. "Phenomenography: A Qualitative Research Methodology in Bangladesh." *International Journal on New Trends in Education and Their Implications* 5 (2): 34–43.
Kim, Kangmoon, and Young-Mee Lee. 2018. "Understanding Uncertainty in Medicine: Concepts and Implications in Medical Education." *Korean Journal of Medical Education* 30 (3): 181–88.
Kimo Takayesu, James, Edward A. Ramoska, Ted R. Clark, Bhakti Hansoti, Joseph Dougherty, Will Freeman, Kevin R. Weaver, Yuchiao Chang, and Eric Gross. 2014. "Factors Associated with Burnout during Emergency Medicine Residency." *Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine* 21 (9): 1031–35.
Knight, Lynn Valerie, and Karen Mattick. 2006. "'When I First Came Here, I Thought Medicine Was Black and White': Making Sense of Medical Students' Ways of Knowing." *Social Science & Medicine* 63 (4): 1084–96.
Kolb, Alice, and David Kolb. 2018. "Eight Important Things to Know about the Experiential Learning Cycle." *Australian Educational Leader* 40 (3): 8–14.
Konkin, D. Jill, and Carol Suddards. 2017. "Students' Experiences of Role, Relationships and Learning in Two Clerkship Models." *Medical Education* 51 (5): 490–97.
Korenstein, Deborah, Laura D. Scherer, Andrew Foy, Lisa Pineles, Alison D. Lydecker, Jill Owczarzak, Larry Magder, et al. 2022. "Clinician Attitudes and Beliefs Associated with More Aggressive Diagnostic Testing." *The American Journal of Medicine* 135 (7): e182–93.
Kuhn, Gloria, Richard Goldberg, and Scott Compton. 2009. "Tolerance for Uncertainty, Burnout, and Satisfaction with the Career of Emergency Medicine." *Annals of Emergency Medicine* 54 (1): 106–13.e6.
Lally, John, and Peter Cantillon. 2014. "Uncertainty and Ambiguity and Their Association with Psychological Distress in Medical Students." *Academic Psychiatry: The Journal of the American Association of Directors of Psychiatric Residency Training and the Association for Academic Psychiatry* 38 (3): 339–44.
Land, Ray. 2016. "Toil and Trouble: Threshold Concepts as a Pedagogy of Uncertainty." *Threshold Concepts in Practice*. https://brill.com/downloadpdf/book/edcoll/9789463005128/BP000003.pdf.
Larsson, Jan, and Inger Holmström. 2007. "Phenomenographic or Phenomenological Analysis: Does It Matter? Examples from a Study on Anaesthesiologists' Work." *International Journal of Qualitative Studies on Health and Well-Being* 2 (1): 55–64.
Lave, Jean, and Etienne Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.
Lawton, Rebecca, Olivia Robinson, Rebecca Harrison, Suzanne Mason, Mark Conner, and Brad Wilson. 2019. "Are More Experienced Clinicians Better Able to Tolerate Uncertainty and Manage Risks? A Vignette Study of Doctors in Three NHS Emergency Departments in England." *BMJ Quality & Safety* 28 (5): 382–88.
Lehmann, H. Peter, and Rex B. Conn. 1979. "SI Units." *CRC Critical Reviews in Clinical Laboratory Sciences* 10 (2): 147–70.
Lemaire, Jane B., and Jean E. Wallace. 2017. "Burnout among Doctors." *BMJ* 358 (July): j3360.
Leung, Lawrence. 2015. "Validity, Reliability, and Generalizability in Qualitative Research." *Journal of Family Medicine and Primary Care* 4 (3): 324–27.

Liou, Kevin T., Daniel S. Jamorabo, Rabih M. Geha, Constance M. Crawford, Paul George, and Fred J. Schiffman. 2019. “Foreign Bodies: Is It Feasible to Develop Tolerance for Ambiguity among Medical Students through Equine-Facilitated Learning?” *Medical Teacher* 41 (8): 960–62.
Low, Jacqueline. 2019. “A Pragmatic Definition of the Concept of Theoretical Saturation.” *Sociological Focus* 52 (2): 131–39.
Luborsky, Mark R., and Robert L. Rubinstein. 1995. “Sampling in Qualitative Research: Rationale, Issues, and Methods.” *Research on Aging* 17 (1): 89–113.
Lucas, Patricia J., Janis Baird, Lisa Arai, Catherine Law, and Helen M. Roberts. 2007. “Worked Examples of Alternative Methods for the Synthesis of Qualitative and Quantitative Research in Systematic Reviews.” *BMC Medical Research Methodology* 7 (January): 4.
Luther, Vera P., and Sonia J. Crandall. 2011. “Commentary: Ambiguity and Uncertainty: Neglected Elements of Medical Education Curricula?” *Academic Medicine: Journal of the Association of American Medical Colleges*.
Malterud, K. 2001. “Qualitative Research: Standards, Challenges, and Guidelines.” *The Lancet* 358 (9280): 483–88.
Marton, Ference. 1981. “Phenomenography ? Describing Conceptions of the World around Us.” *Instructional Science* 10 (2): 177–200.
———. 1986. “Phenomenography—A Research Approach to Investigating Different Understandings of Reality.” *Journal of Thought* 21 (3): 28–49.
———. 2000. “The Structure of Awareness.” *Phenomenography* 10216: 102–16.
Marton, Ference, and Shirley Booth. 2013. *Learning and Awareness*. Routledge.
Marton, Ference, Maj Asplund Carlsson, and László Halász. 1992. “Differences in Understanding and the Use of Reflective Variation in Reading.” *The British Journal of Educational Psychology* 62 (1): 1–16.
Marton, Ference, and Wing Yan Pong. 2005. “On the Unit of Description in Phenomenography.” *Higher Education Research & Development* 24 (4): 335–48.
McCulloch, P., A. Kaul, G. F. Wagstaff, and J. Wheatcroft. 2005. “Tolerance of Uncertainty, Extroversion, Neuroticism and Attitudes to Randomized Controlled Trials among Surgeons and Physicians.” *The British Journal of Surgery* 92 (10): 1293–97.
McHugh, Marry L. 2012. “Interrater Reliability: The Kappa Statistic.” *Biochemia Medica*. https://doi.org/10.11613/bm.2012.031.
McKinley, Jim. 2015. “Critical Argument and Writer Identity: Social Constructivism as a Theoretical Framework for EFL Academic Writing.” *Critical Inquiry in Language Studies* 12 (3): 184–207.
Mcleod, Saul. 2018. “Maslow’s Hierarchy of Needs.” 2018. https://canadacollege.edu/dreamers/docs/Maslows-Hierarchy-of-Needs.pdf.
Medical Licensing Assessment. 2022. “Medical Licensing Assessment.” 2022. https://www.gmc-uk.org/education/medical-licensing-assessment.
“Medical Schools Council.” 2021. 2021. https://www.medschools.ac.uk/.
———. 2022. “Medical Schools.” 2022. https://www.medschools.ac.uk/studying-medicine/medical-schools.
Ménard, Lyne, and Savithiri Ratnapalan. 2013. “Teaching Moment: Reflection in Medicine: Models and Application.” *Canadian Family Physician Medecin de Famille Canadien* 59 (1): 105–7, e57–59.
Merriënboer, Jeroen J. G. van, and John Sweller. 2010. “Cognitive Load Theory in Health Professional Education: Design Principles and Strategies.” *Medical Education* 44 (1): 85–93.
Merrill, J. M., Z. Camacho, L. F. Laux, R. Lorimor, J. I. Thornby, and C. Vallbona. 1994. “Uncertainties and Ambiguities: Measuring How Medical Students Cope.” *Medical Education* 28 (4): 316–22.
Meyer, Jan H. F., and Ray Land. 2003. “Threshold Concepts and Troublesome Knowledge: Linkages to Ways of Thinking and Practising within the Disciplines.” 2003. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.476.3389&rep=rep1&type=pdf.
Mishel, M. H. 1983. “Adjusting the Fit: Development of Uncertainty Scales for Specific Clinical

Populations." *Western Journal of Nursing Research* 5 (4): 355–70.
Moffett, Jenny, Jennifer Hammond, Paul Murphy, and Teresa Pawlikowska. 2021. "The Ubiquity of Uncertainty: A Scoping Review on How Undergraduate Health Professions' Students Engage with Uncertainty." *Advances in Health Sciences Education: Theory and Practice* 26 (3): 913–58.
Moyano-Díaz, Emilio. 2016. "Building the Concept of Happiness for Adults from Phenomenography." *Universum. Revista de Humanidades Y Ciencias Sociales* 31 (2): 141–56.
Munn, Zachary, Micah D. J. Peters, Cindy Stern, Catalin Tufanaru, Alexa McArthur, and Edoardo Aromataris. 2018. "Systematic Review or Scoping Review? Guidance for Authors When Choosing between a Systematic or Scoping Review Approach." *BMC Medical Research Methodology* 18 (1): 1–7.
Murray Longmore, J., Murray Longmore, Ian Wilkinson, Edward Davidson, Alexander Foulkes, and Ahmad Mafi. 2010. *Oxford Handbook of Clinical Medicine*. OUP Oxford.
Nalliah, Sivalingam. 2014. "Applying the Learning Theories to Medical Education: A Commentary." *International E-Journal of Science, Medicine & Education* 8 (1): 50–57.
Neges. 2013. "Non-Dualism and World: Ontological Questions in the Non-Dualizing Mode of Discourse." *Constructivist Foundations*. https://constructivist.info/8/2.pdf#page=22.
Nelson, James. 2017. "Using Conceptual Depth Criteria: Addressing the Challenge of Reaching Saturation in Qualitative Research." *Qualitative Research: QR* 17 (5): 554–70.
Nevalainen, Maarit, Liisa Kuikka, Lena Sjoberg, Johan Eriksson, and Kaisu Pitkala. 2012. "Tolerance of Uncertainty and Fears of Making Mistakes among Fifth-Year Medical Students." *Family Medicine* 44 (4): 240–46.
Nevalainen, T. Mantyranta, and K. H. Pitkala. 2010. "Facing Uncertainty as a Medical student—A Qualitative Study of Their Reflective Learning Diaries and Writings on Specific Themes during the First Clinical Year." *Patient Education and Counseling* 78 (2): 218–23.
"News and Events." 2021. *Bulletin of the History of Medicine* 95 (4): 590–92.
O'Grady, Paul. 2002. "Ontological Relativism." In *Relativism*, 53–88. Acumen Publishing.
Olson, Maren E., Emily Borman-Shoap, Karen Mathias, Timothy L. Barnes, and Andrew P. J. Olson. 2018. "Case-Based Simulation Empowering Pediatric Residents to Communicate about Diagnostic Uncertainty." *Diagnosis (Berlin, Germany)* 5 (4): 243–48.
Otter, A. I. 2021. "Otter Voice Meeting Notes."
Palinkas, Lawrence A., Sarah M. Horwitz, Carla A. Green, Jennifer P. Wisdom, Naihua Duan, and Kimberly Hoagwood. 2015. "Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research." *Administration and Policy in Mental Health* 42 (5): 533–44.
Pang, Ming Fai. 2003. "Two Faces of Variation: On Continuity in the Phenomenographic Movement." *Scandinavian Journal of Educational Research* 47 (2): 145–56.
Papanagnou, Dimitrios, Nethra Ankam, David Ebbott, and Deborah Ziring. 2021. "Towards a Medical School Curriculum for Uncertainty in Clinical Practice." *Medical Education Online* 26 (1): 1972762.
Patel, Priya, Jason Hancock, Morwenna Rogers, and Samuel R. Pollard. 2022. "Improving Uncertainty Tolerance in Medical Students: A Scoping Review." *Medical Education*, July. https://doi.org/10.1111/medu.14873.
Persky, Adam M., and Jennifer D. Robinson. 2017. "Moving from Novice to Expertise and Its Implications for Instruction." *American Journal of Pharmaceutical Education* 81 (9): 6065.
Pitt, Edd. 2014. "Feedback in Higher Education: Exploring Students' Appraisal, Comprehension and Utilisation." Phd, University of Liverpool. https://kar.kent.ac.uk/47524/.
Pluye, Pierre, Marie-Pierre Gagnon, Frances Griffiths, and Janique Johnson-Lafleur. 2009. "A Scoring System for Appraising Mixed Methods Research, and Concomitantly Appraising Qualitative, Quantitative and Mixed Methods Primary Studies in Mixed Studies Reviews." *International Journal of Nursing Studies* 46 (4): 529–46.
Pope, Catherine, and Nicholas Mays. 2020. *Qualitative Research in Health Care*. John Wiley & Sons.

PROSPERO. 2022. “PROSPERO.” November 21, 2022. https://www.crd.york.ac.uk/PROSPERO/.
quoteinvestigator.com. 2018. “Quoteinvestigator.com.” Quoteinvestigator.com. November 18, 2018. https://quoteinvestigator.com/2018/11/18/know-trouble/.
Radhakrishna, S. 2015. “Culture of Blame in the National Health Service; Consequences and Solutions.” *British Journal of Anaesthesia* 115 (5): 653–55.
Randall, Virginia, Robert Brooks, Agnes Montgomery, and Lauren McNally. 2018. “Threshold Concepts in Medical Education.” *MedEdPublish* 7. https://www.mededpublish.org/manuscripts/1866?platform=hootsuite.
Randall, Virginia, and Charisse Villareal. 2020. “‘It’s Okay to Say’I Don't Know'': Medical Students Use Transformative Thinking to Cope with Ambiguity and Uncertainty.” *MedEd Publish* 9. https://www.academia.edu/download/77504635/2773-20320.pdf.
Rands, Melissa, and Ann M. Gansemer-Topf. 2016. “Phenomenography: A Methodological Approach for Assessment in Student Affairs.” *Journal of Student Affairs Inquiry* 1 (2): 1.
Reid, Anne-Marie, Jeremy M. Brown, Julie M. Smith, Alexandra C. Cope, and Susan Jamieson. 2018. “Ethical Dilemmas and Reflexivity in Qualitative Research.” *Perspectives on Medical Education* 7 (2): 69–75.
Reis-Dennis, Samuel, Martha S. Gerrity, and Gail Geller. 2021. “Tolerance for Uncertainty and Professional Development: A Normative Analysis.” *Journal of General Internal Medicine* 36 (8): 2408–13.
Richardson, John T. E. 1999. “The Concepts and Methods of Phenomenographic Research.” *Review of Educational Research* 69 (1): 53–82.
Riddell, Nathan, and Samuel King. 2016. “Near-Peer Teaching in Medical Education.” *Medical Teacher*. https://doi.org/10.3109/0142159x.2015.1083964.
Robinson, Oliver C. 2014. “Sampling in Interview-Based Qualitative Research: A Theoretical and Practical Guide.” *Qualitative Research in Psychology* 11 (1): 25–41.
Rogers, Erin, Emily Griffin, William Carnie, Joseph Melucci, and Robert J. Weber. 2017. “A Just Culture Approach to Managing Medication Errors.” *Hospital Pharmacy* 52 (4): 308–15.
Runesson, Ulla. 2005. “Beyond Discourse and Interaction. Variation: A Critical Aspect for Teaching and Learning Mathematics.” *Cambridge Journal of Education* 35 (1): 69–87.
Sadler, Jonathan, Chris Carey, Andrew Smith, Helen Smith, Robert Stephens, and Claire Frith. 2017. “Science, Skills and Safety: A Framework for Medical Student Education in Anaesthesia, Intensive Care, Pain and Perioperative Medicine.” November 2017. https://rcoa.ac.uk/sites/default/files/documents/2019-08/ComptencyFrameworkDocument2017.pdf.
Säljö, Roger. 1994. “Minding Action: Conceiving of the World versus Participating in Cultural Practices.” *Nordisk Pedagogik* 14 (2): 71–80.
———. 1997. “Talk as Data and Practice — a Critical Look at Phenomenographic Inquiry and the Appeal to Experience.” *Higher Education Research & Development* 16 (2): 173–90.
Sam, Amir H., Rebecca K. Wilson, Martin Lupton, Colin Melville, Omid Halse, Joanne Harris, and Karim Meeran. 2020. “Clinical Prioritisation Questions: A Novel Assessment Tool to Encourage Tolerance of Uncertainty?” *Medical Teacher* 42 (4): 416–21.
Sandars, John. 2009. “The Use of Reflection in Medical Education: AMEE Guide No. 44.” *Medical Teacher* 31 (8): 685–95.
Sandbergh, Jörgen. 1997. “Are Phenomenographic Results Reliable?” *Higher Education Research & Development* 16 (2): 203–12.
Schor, R., D. Pilpel, and J. Benbassat. 2000. “Tolerance of Uncertainty of Medical Students and Practicing Physicians.” *Medical Care* 38 (3): 272–80.
Schwandt. 2000. “Three Epistemological Stances for Qualitative Inquiry: Interpretivism, Hermeneutics, and Social Constructionism.” *Handbook of Qualitative Research*. https://experts.illinois.edu/en/publications/three-epistemological-stances-for-qualitative-inquiry-interpretiv.

Scott, Ashley, Mark Sudlow, Emily Shaw, and James Fisher. 2020. “Medical Education, Simulation and Uncertainty.” *The Clinical Teacher* 17 (5): 497–502.
Seel, Norbert M. 2011. *Encyclopedia of the Sciences of Learning*. Springer Science & Business Media.
Shepherd, Lisa, Ryan Gauld, Sayra M. Cristancho, and Saad Chahine. 2020. “Journey into Uncertainty: Medical Students’ Experiences and Perceptions of Failure.” *Medical Education* 54 (9): 843–50.
Sherman, Robert R., and Rodman B. Webb. 2004. *Qualitative Research In Education*. Routledge.
Simpkin, Arabella L., and Katrina A. Armstrong. 2019. “Communicating Uncertainty: A Narrative Review and Framework for Future Research.” *Journal of General Internal Medicine* 34 (11): 2586–91.
Simpkin, Arabella L., Alisa Khan, Daniel C. West, Briana M. Garcia, Theodore C. Sectish, Nancy D. Spector, and Christopher P. Landrigan. 2018. “Stress From Uncertainty and Resilience Among Depressed and Burned Out Residents: A Cross-Sectional Study.” *Academic Pediatrics* 18 (6): 698–704.
Simpkin, Arabella L., Zachary Murphy, and Katrina A. Armstrong. 2019. “A Randomized Experimental Study to Assess the Effect of Language on Medical Students’ Anxiety due to Uncertainty.” *Diagnosis (Berlin, Germany)* 6 (3): 269–76.
Simpkin, Arabella L., and Richard M. Schwartzstein. 2016a. “Tolerating Uncertainty—the next Medical Revolution?” *The New England Journal of Medicine* 375 (18). https://ora.ox.ac.uk/objects/uuid:29cef5e2-0680-40ea-b511-4911723b7db2/files/m3d9b465139a0af33ebfad4679dd08a92.
———. 2016b. “Tolerating Uncertainty - The Next Medical Revolution?” *The New England Journal of Medicine* 375 (18): 1713–15.
Smith, A. F., J. Sadler, and C. Carey. 2018. “Anaesthesia and the Undergraduate Medical Curriculum.” *British Journal of Anaesthesia* 121 (5): 993–96.
Smith, Andrew, Chris Carey, Jonathan Sadler, Helen Smith, Robert Stephens, and Claire Frith. 2018. “Undergraduate Education in Anaesthesia and Related Specialties: A Compendium of Current Practice and Resources for Educators.” *MedEdPublish* 7. https://scholar.archive.org/work/etjaqwefhvf6fgzbeaksdy5pxy/access/wayback/https://www.mededpublish.org/MedEdPublish/PDF/1452-7703.pdf.
Smith, Andrew, Christopher Carey, Jonathan Sadler, Helen Smith, Robert Stephens, and Claire Frith. 2019. “Undergraduate Education in Anaesthesia, Intensive Care, Pain, and Perioperative Medicine: The Development of a National Curriculum Framework.” *Medical Teacher* 41 (3): 340–46.
Smithson, Michael. 1993. “Ignorance and Science: Dilemmas, Perspectives, and Prospects.” *Knowledge* 15 (2): 133–56.
Sobal, Jeffery. 1992. “RELIABILITY OF BUDNER’S INTOLERANCE OF AMBIGUITY SCALE IN MEDICAL STUDENTS.” *Psychological Reports*. https://doi.org/10.2466/pr0.71.5.15-18.
Sommers, Lucia S., Laura Morgan, Lisa Johnson, and Kay Yatabe. 2007. “Practice Inquiry: Clinical Uncertainty as a Focus for Small-Group Learning and Practice Improvement.” *Journal of General Internal Medicine* 22 (2): 246–52.
Sonneman, Ulrich. 1954. *Existence and Therapy: An Introduction to Phenomenological Psychology and Existential Analysis*. Vol. 381. New York City: Grune & Stratton.
Steiner, Jeanne L. 2006. “Managing Risk: Systems Approach versus Personal Responsibility for Hospital Incidents.” *The Journal of the American Academy of Psychiatry and the Law* 34 (1): 96–98.
Stenfors-Hayes, Terese, Hakan Hult, and Madeleine A. Dahlgren. 2013. “A Phenomenographic Approach to Research in Medical Education.” *Medical Education* 47 (3): 261–70.
Stephens, Georgina C., M. Nazmul Karim, Mahbub Sarkar, Adam B. Wilson, and Michelle D. Lazarus. 2022. “Reliability of Uncertainty Tolerance Scales Implemented Among Physicians and Medical Students: A Systematic Review and Meta-Analysis.” *Academic Medicine: Journal of the Association of American Medical Colleges* 97 (9): 1413–22.

Stephens, Georgina C., Michelle D. Lazarus, Mahbub Sarkar, M. Nazmul Karim, and Adam B. Wilson. 2022. “Identifying Validity Evidence for Uncertainty Tolerance Scales: A Systematic Review.” *Medical Education*, December. https://doi.org/10.1111/medu.15014.

Stephens, Georgina C., M. Nazmul Karim, Mahbub Sarkar, Adam B. Wilson, and Michelle D. Lazarus. 2022. “Reliability of Uncertainty Tolerance Scales Implemented Among Physicians and Medical Students.” *Academic Medicine*. https://doi.org/10.1097/acm.0000000000004641.

Stephens, Georgina C., Charlotte E. Rees, and Michelle D. Lazarus. 2021. “Exploring the Impact of Education on Preclinical Medical Students’ Tolerance of Uncertainty: A Qualitative Longitudinal Study.” *Advances in Health Sciences Education: Theory and Practice* 26 (1): 53–77.

Stephens, Georgina C., Mahbub Sarkar, and Michelle D. Lazarus. 2022. “‘A Whole Lot of Uncertainty’: A Qualitative Study Exploring Clinical Medical Students’ Experiences of Uncertainty Stimuli.” *Medical Education*, February. https://doi.org/10.1111/medu.14743.

Stojan, Jennifer N., Michelle Daniel, Sarah Hartley, and Larry Gruppen. 2022. “Dealing with Uncertainty in Clinical Reasoning: A Threshold Model and the Roles of Experience and Task Framing.” *Medical Education* 56 (2): 195–201.

Stolz, Steven A. 2020. “Phenomenology and Phenomenography in Educational Research: A Critique.” *Educational Philosophy and Theory* 52 (10): 1077–96.

Stopford, Richard. 2021. “Threshold Concepts and Certainty: A Critical Analysis of ‘troublesomeness.’” *Higher Education*. https://doi.org/10.1007/s10734-020-00628-w.

Strout, Tania D., Marij Hillen, Caitlin Gutheil, Eric Anderson, Rebecca Hutchinson, Hannah Ward, Hannah Kay, Gregory J. Mills, and Paul K. J. Han. 2018. “Tolerance of Uncertainty: A Systematic Review of Health and Healthcare-Related Outcomes.” *Patient Education and Counseling* 101 (9): 1518–37.

Sturdy, Steve. 2007. “Scientific Method for Medical Practitioners: The Case Method of Teaching Pathology in Early Twentieth-Century Edinburgh.” *Bulletin of the History of Medicine* 81 (4): 760–92.

“Sussex Code of Practice.” 2021. 2021. https://www.sussex.ac.uk/staff/research/rqi/rqi_information_and_support/rqi_ref/code-of-practice-ref2021.

Teeter, Preston, and Jörgen Sandberg. 2017. “Constraining or Enabling Green Capability Development? How Policy Uncertainty Affects Organizational Responses to Flexible Environmental Regulations.” *British Journal of Management* 28 (4): 649–65.

Ten Cate, Th J., Rashmi A. Kusurkar, and Geoffrey C. Williams. 2011. “How Self-Determination Theory Can Assist Our Understanding of the Teaching and Learning Processes in Medical Education. AMEE Guide No. 59.” *Medical Teacher* 33 (12): 961–73.

Thomas, James, and Angela Harden. 2008. “Methods for the Thematic Synthesis of Qualitative Research in Systematic Reviews.” *BMC Medical Research Methodology* 8 (July): 45.

Tight, Malcolm. 2016. “Phenomenography: The Development and Application of an Innovative Research Design in Higher Education Research.” *International Journal of Social Research Methodology* 19 (3): 319–38.

Trem, K. R. 2017. “Selecting an Appropriate Research Sample for a Phenomenographic Study of Values.” http://eprints.leedsbeckett.ac.uk/4096/1/.

Tricco, Andrea C., Erin Lillie, Wasifa Zarin, Kelly K. O’Brien, Heather Colquhoun, Danielle Levac, David Moher, et al. 2018. “PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation.” *Annals of Internal Medicine* 169 (7): 467–73.

Trigwell, Keith. 2000. “A Phenomenographic Interview on Phenomenography.” *Phenomenography* 1: 62–82.

Trotter, Robert T., 2nd. 2012. “Qualitative Research Sample Design and Sample Size: Resolving and Unresolved Issues and Inferential Imperatives.” *Preventive Medicine* 55 (5): 398–400.

Turner, Simon R., Jonathan White, and Cheryl Poth. 2012. “Twelve Tips for Developing a near-Peer Shadowing Program to Prepare Students for Clinical Training.” *Medical Teacher* 34 (10): 792–95.

Voltaire. Letter to King Fredrick II of Prussia. 1767. “Letter,” April 6, 1767.
Walsh, Eleanor. 2000. “Phenomenographic Analysis of Interview Transcripts.” *Phenomenography* 1: 19–33.
Watts, Simon. 2014. “User Skills for Qualitative Analysis: Perspective, Interpretation and the Delivery of Impact.” *Qualitative Research in Psychology* 11 (1): 1–14.
Wayne, Sharon, Deborah Dellmore, Lisa Serna, Roger Jerabek, Craig Timm, and Summers Kalishman. 2011. “The Association between Intolerance of Ambiguity and Decline in Medical Students’ Attitudes toward the Underserved.” *Academic Medicine: Journal of the Association of American Medical Colleges* 86 (7): 877–82.
Weissenstein, Anne, Sandra Ligges, Britta Brouwer, Bernhard Marschall, and Hendrik Friederichs. 2014. “Measuring the Ambiguity Tolerance of Medical Students: A Cross-Sectional Study from the First to Sixth Academic Years.” *BMC Family Practice* 15 (January): 6.
Weurlander, Maria, Annalena Lönn, Astrid Seeberger, Håkan Hult, Robert Thornberg, and Annika Wernerson. 2019. “Emotional Challenges of Medical Students Generate Feelings of Uncertainty.” *Medical Education* 53 (10): 1037–48.
Williams, G. C., R. B. Saizow, and R. M. Ryan. 1999. “The Importance of Self-Determination Theory for Medical Education.” *Academic Medicine: Journal of the Association of American Medical Colleges* 74 (9): 992–95.
Wray, Charlie M., and Lawrence K. Loo. 2015. “The Diagnosis, Prognosis, and Treatment of Medical Uncertainty.” *Journal of Graduate Medical Education* 7 (4): 523–27.
Yardley. 2000. “Dilemmas in Qualitative Health Research.” *Psychology & Health* 15 (2): 215–28.
Yardley, Sarah, Pim W. Teunissen, and Tim Dornan. 2012. “Experiential Learning: AMEE Guide No. 63.” *Medical Teacher* 34 (2): e102–15.
Yates, Christine, Helen Partridge, and Christine Bruce. 2012. “Exploring Information Experiences through Phenomenography.” *Library and Information Research* 36 (112): 96–119.
Yazdani, Shahram, Mohammad Reza Andarvazh, and Leila Afshar. 2020. “What Is Hidden in Hidden Curriculum? A Qualitative Study in Medicine.” *Journal of Medical Ethics and History of Medicine*. https://doi.org/10.18502/jmehm.v13i4.2843.
Yazdankhahfard, Mohammadreza, Fariba Haghani, and Athar Omid. 2019. “The Balint Group and Its Application in Medical Education: A Systematic Review.” *Journal of Education and Health Promotion* 8 (June): 124.
“Zoom.” 2021. Zoom. May 14, 2021. https://explore.zoom.us/en/about/.