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Towards a new understanding of uncertainty in medical education

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Abstract

Rationale, aims, and objectives: Uncertainty is a complex and constant phenomenon in clinical practice. How medical students recognize and respond to uncertainty impacts on their well-being, career choices, and attitudes towards patients. It has been suggested that curricula should do more to prepare medical students for an uncertain world. In order to teach medical students about uncertainty, we need to understand how uncertainty has been conceptualized in the literature to date. The aim of this article is to explore existing models of uncertainty and to develop a framework of clinical uncertainty to aid medical education.

Method: A scoping literature review was performed to identify conceptual models of uncertainty in healthcare. Content and inductive analyses were performed to explore three dimensions of clinical uncertainty: sources of uncertainty, subjective influencers and responses to uncertainty.

Results: Nine hundred one references were identified using our search strategy, of which, 24 met our inclusion criteria. It was possible to classify these conceptual models using one or more of three dimensions of uncertainty; sources, subjective influencers, and responses. Exploration and further classification of these dimensions led to the development of a framework of uncertainty for medical education.

Conclusion: The developed framework of clinical uncertainty highlights sources, subjective influencers, responses to uncertainty, and the dynamic relationship among these elements. Our framework illustrates the different aspects of knowledge as a source of uncertainty and how to distinguish between those aspects. Our framework highlights the complexity of sources of uncertainty, especially when including uncertainty arising from relationships and systems. These sources can occur in combination. Our framework is also novel in how it describes the impact of influencers such as personal characteristics, experience, and affect on perceptions of and responses to uncertainty. This framework can be used by educators and curricula developers to help understand and teach about clinical uncertainty.

KEYWORDS

curriculum, medical education, medical student, medicine, professionalism, uncertainty



1 | INTRODUCTION

Uncertainty is at the core of clinical practice. Uncertainty can be found in education and research, diagnosis, treatment, outcomes, patient, and doctor experiences.^{1,2} Doctors' responses to uncertainty impact upon anxiety levels, work-related stress, and burnout.³⁻⁶ At any stage of their careers, doctors' uncertainty can result in the excessive ordering of diagnostic tests and increased admission rates.⁷⁻¹⁰ Uncertainty in clinical decision making may delay delivery of patient care, cause clinicians to withhold information from patients, or express information in ways distressing to patients.^{11,12} These maladaptive responses suggest that doctors could benefit from additional guidance on how to work in the presence of uncertainty, starting from their time in medical school.

The transition from structured education to clinical environments means that medical students progress into a world that is increasingly uncertain and can lack the skills to navigate it. Uncertainty can affect medical students' well-being, career choices, and their attitudes towards patients.^{2,13,14} Learning to work in the presence of uncertainty, the 'grey-scale space'¹⁵ (p. 1713) of clinical practice is a crucial aspect of becoming a doctor. It has been argued that curricula and training programmes could do more to prepare our future doctors for a world of uncertainty.^{1,3,15-18} It has also been suggested that teaching on uncertainty should be a part of every medical school's curriculum,^{16,17} with educators demonstrating to students how to practise medicine in an uncertain world.¹⁵ But to teach about uncertainty, we require the ability to conceptualize what uncertainty means in the context of clinical practice in a way that is clear, meaningful, based on validated research and can easily be communicated to students.

Uncertainty has been conceptualized and explored in many disciplines including psychology, medicine, nursing, anthropology, sociology, philosophy, mathematics, statistics, economics, decision theory, and engineering.¹⁹⁻²⁵ The purpose of this paper is to address how clinical uncertainty can be conceptualized for medical education, and so the focus here is on healthcare literature. To examine theorizations from other disciplines is beyond the scope of this paper; readers are directed to the following comprehensive reviews.^{19,20,26} A literature search was performed to identify conceptual models of uncertainty in healthcare. Included models were analysed using content and inductive analyses, and the results synthesized to develop a framework of uncertainty in healthcare for students and educators. We then discuss how this framework could be applied to general teaching and learning strategies to help medical students to learn about clinical uncertainty. In order to appreciate this framework, it is first important to understand how clinical uncertainty can be defined.

1.1 | Defining clinical uncertainty

To help understand clinical uncertainty and how its definition can impact medical education, definitions from the fields of medicine, nursing, psychology, and medical sociology were compared

(see Table 1). This list is not exhaustive; these definitions reflect the complexity of clinical care and place an emphasis on different dimensions of uncertainty in clinical practice.

Definitions of uncertainty in healthcare can be viewed to reveal three core dimensions of uncertainty. These dimensions are sources of uncertainty,^{20,22,27-29} the subjective nature of uncertainty,^{20,22,27-30} and responses to uncertainty.^{14,20,30}

The most common dimension in definitions of uncertainty is its source. Sources highlighted in Table 1 include a lack of knowledge,^{27,29} interpreting probabilities,^{20,27,28} ambiguity,^{27,28} complexity,^{27,28} and difficult or unfamiliar clinical situations.¹⁴ A classification theorized by Sommers³⁰ describes sources of uncertainty as stemming from knowledge, relationships, and complex systems. For uncertainty to exist, there needs to be a state of awareness, or meta-cognition, of these sources. The definitions in Table 1 paint a picture of a state of transition, where the person experiencing this uncertainty feels that they lack either the knowledge or skills to proceed on a definite path, a common occurrence in clinical practice. This transitional cognitive state is described as 'confusion, conflict, stuckness, unease, and/or discomfort' when describing uncertainty in general practice.³⁰ (p. 6)

A second dimension of uncertainty is its subjective nature. When in a transitional cognitive state, the perception of uncertainty depends on the individual appraising a situation, as highlighted in the subjective nature of six definitions in Table 1.^{20,22,27-30} Patients and healthcare providers bring unique influencers such as personal characteristics and experiences to the situations that they face,²² and therefore, their experiences of uncertainty can be defined as subjective and unique for each person and each situation. As a result of this cognitive state, people can respond in a variety of ways when faced with an uncertain situation.

A third dimension of uncertainty involves the responses that it elicits, as seen in definitions by Gerrity,¹⁴ Penrod,²⁰ and Sommers³⁰ in Table 1. Responses to uncertainty in these definitions are cognitive, emotional, and behavioural. This pattern of responses to uncertainty can be seen in the actions of doctors and medical students.¹³ These actions can be adaptive or maladaptive. Due to the subjective nature of uncertainty, how doctors and medical students respond will be influenced by their perceptions of the situation they are experiencing, making uncertainty a dynamic and varying state.

The idea of sources of uncertainty causing a cognitive state which results in a range of responses informs the definition which will be used in this paper. We define uncertainty as *the dynamic, subjective perception of not knowing what to think, feel, or do*. Our definition builds on definitions by Han,²⁸ Sommers,³⁰ and Penrod.²⁰ Our definition brings the three dimensions discussed above together. First, for uncertainty to exist, there needs to be an awareness of a source of uncertainty. Second, uncertainty is dynamic, and perceptions of it can differ from person to person. Third, we can respond to uncertainty in different ways. Uncertainty affects how we think (cognition), feel (emotions) or act (behaviours). This definition forms the theoretical framework used in this paper to explore conceptual models of uncertainty in healthcare literature.

TABLE 1 A selection of definitions of uncertainty

Author and references	Year	Definition	Dimension(s) of uncertainty that definition addresses		
			Source	Subjective cognitive state	Responses to uncertainty
Penrod ²⁰ (p. 241)	2001	'Uncertainty is a dynamic state in which there is a perception of being unable to assign probabilities for outcomes that prompts a discomforting, uneasy sensation that may be affected (reduced or escalated) through cognitive, emotive, or behavioural reactions, or by the passage of time and changes in the perception of circumstances.'	*	*	*
Mishel ²² (p. 225)	1988	'It is the cognitive state created when the person cannot adequately structure or categorize an event because of the lack of sufficient cues.'	*	*	
Brashers ²⁷ (p. 478)	2001	'Uncertainty exists when details of situations are ambiguous, complex, unpredictable, or probabilistic; when information is unavailable or inconsistent; and when people feel insecure in their own state of knowledge or the state of knowledge in general.'	*	*	
Han et al ²⁸ (p. 1)	2015	'Uncertainty represents a multi-dimensional phenomenon consisting of conscious awareness of ignorance arising from distinct sources: probability, ambiguity and complexity.'	*	*	
Bhise ²⁹ (p. 113)	2018	(definition of diagnostic uncertainty) 'Subjective perception of an inability to provide an accurate explanation of the patient's health problem.'	*	*	
Sommers ³⁰ (p. 3)	2003	'A subjective perception of not knowing what to think or what to do.'		*	*
Gerrity et al ¹⁴ (p. 726)	1990	(defining affective reactions to uncertainty in patient care) as (a) 'the emotional reactions and concerns engendered in physicians who face clinical situations that are unfamiliar or not easily resolved' and (b) 'the behaviours used by physicians to cope with those emotions and concerns'	*		*

^aThe "*" has been used to highlight to the reader the dimension(s) of uncertainty addressed in each definition.

1.2 | A note on ambiguity

The term ambiguity also needs to be defined here, as it is frequently used interchangeably when perspectives of uncertainty are studied in healthcare professionals and students.^{31,32} The Oxford English Dictionary defines ambiguity as: 'The fact or quality of being difficult to categorize or identify, esp. due to changeable or contradictory qualities or characteristics', which is the definition that will be used in this paper. Uncertainty and ambiguity, as concepts, are not equal.³⁴ Defining ambiguity as something which is difficult to interpret resonates within complex healthcare environments, where sources of information and relationships with other people can be interpreted in multiple ways. As such, ambiguity can be thought of as a stimulus which may provoke uncertainty but is not equivalent to uncertainty.^{22,31,32}

Recently, there has been debate about how uncertainty can and has been conceptualized in healthcare.³⁵ The authors argued that conceptual models of uncertainty are imperfect, and that existing models can be tailored to fit a specific purpose. The aim of this paper, therefore, is to explore existing models of uncertainty in healthcare using

our definition proposed above and to develop a framework of clinical uncertainty to aid in medical education.

2 | METHODS

A scoping review³⁶ was performed to identify conceptual models of uncertainty in the literature which included articles, reviews, books, and book chapters. Once identified, content³⁷ and inductive analyses³⁸ were performed to explore these references. The following databases were searched: Scopus, PubMed, Embase, and CINAHL. The following search terms were used in all three databases: ['uncertain*' OR 'ambig*'] AND ['medic*' OR 'clinic*' OR 'primary care' OR 'hospital' OR 'health*' OR 'physician*' OR 'doctor*' OR 'surgeon*' OR 'general pract*']. The term 'ambig*' was included in the search strategy as it has been used interchangeably with uncertainty by some authors. Searches were restricted to titles only, due to the general nature of the search terms. Databases were searched for publications until December 31, 2019. Only articles, reviews, books, and book chapters written in English were included.

In each database, results were refined by reviewing titles to ensure that those included related to uncertainty (as defined in this paper) in a healthcare setting. Citations from each database were imported into the reference manager Endnote X8.³⁹ Duplicates were removed, and abstracts were read to determine if the reference related to a model or conceptual framework of uncertainty.

A conceptual framework is described as 'ways of thinking about a problem or a study or ways of representing how complex things work the way they do. Different frameworks will emphasize different variables and

outcomes, and their inter-relatedness'.⁴⁰ (p. 313) This definition of a conceptual framework was used as a lens to help determine which material should be included for a full-text review. The terms 'conceptual model' and 'conceptual framework' are used interchangeably in this paper.

When reviewing the full text of a reference, it had to meet at least one of three inclusion criteria: (a) The reference describes a novel conceptual model or framework of uncertainty based on empirical research; (b) the reference describes a novel conceptual model of uncertainty based on a review of the literature; (c) the reference

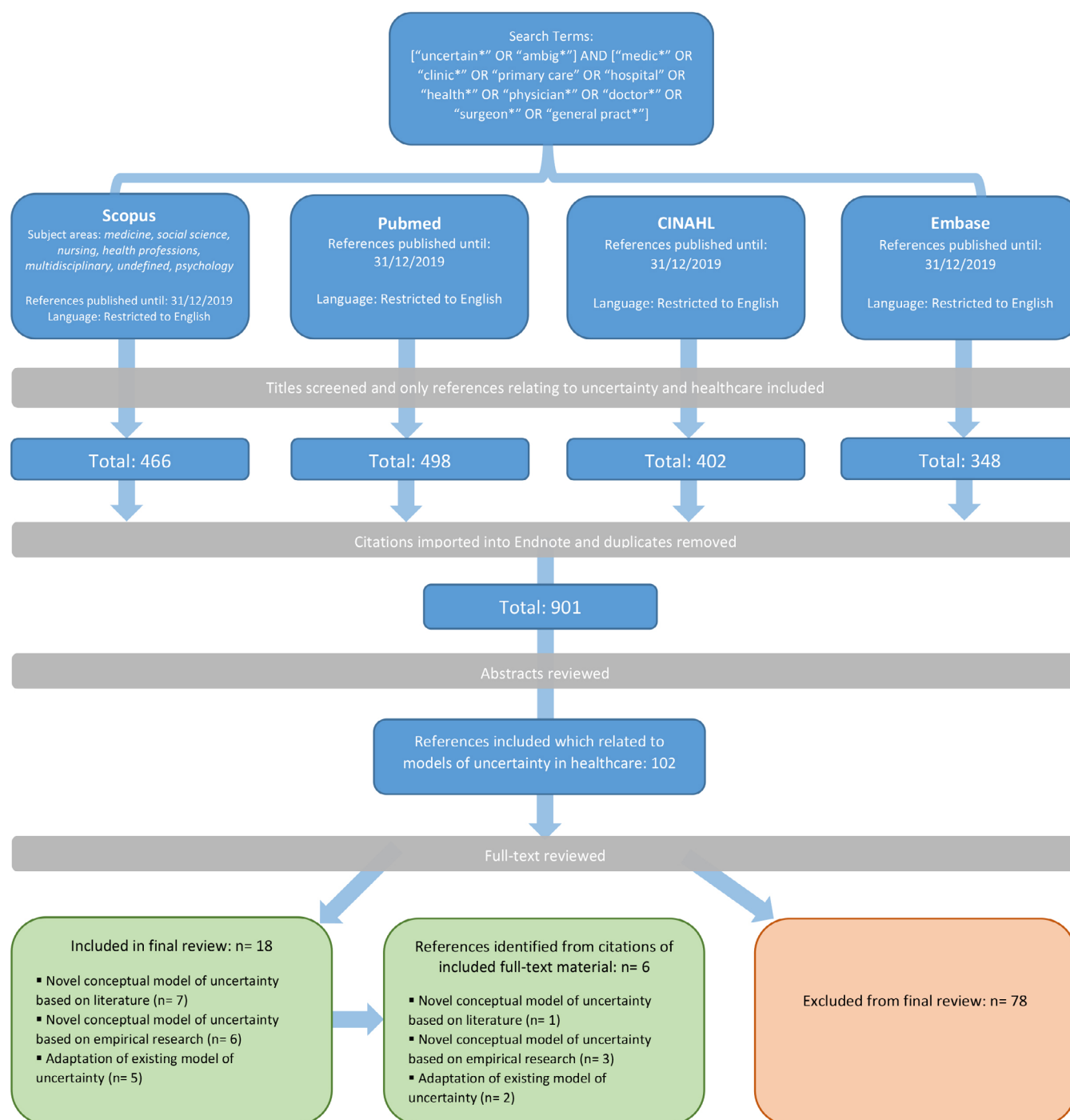


FIGURE 1 Search strategy

amends or adds to existing conceptual models of uncertainty. Details about the methods used in the structure of the conceptual model were recorded for each included reference. The citations of included references were also reviewed and additional material of interest screened. This revealed further references for inclusion. A summary of the search strategy used can be seen in Figure 1.

The three dimensions in the definition of clinical uncertainty proposed in this paper were used as a framework to analyse the included references. To explore each dimension, three readings of each included reference occurred, each looking at a different one of these dimensions: sources of uncertainty, the subjective nature of uncertainty, and responses to uncertainty.

To examine sources of and responses to uncertainty, content analyses³⁷ were performed. The sources of uncertainty identified in each reference were listed. These sources were then analysed using the classification proposed by Sommers³⁰ (knowledge, relationships, and systems). All responses to uncertainty were listed, and the categories of cognitive, emotional, and behavioural responses to uncertainty²⁰ were used to perform the analysis.

An inductive approach³⁸ was used to explore what factors influence uncertainty as a subjective cognitive state (termed subjective influencers). The first author (CL) conducted a close reading of the included references which resulted in the development of subcategories. These subcategories were discussed with the coauthors, and a mutual consensus was reached.

The results of the analysis of each dimension of uncertainty were then combined to create a framework of uncertainty for medical education. This synthesis brought together the results of the two content analyses and the inductive analysis, with consideration for any interactions between elements. The synthesis was refined by all authors through discussion and reflection on the findings of each analysis.

3 | RESULTS

After removing duplicates, 901 references were identified for abstract review. One hundred two references met the criteria for full-text review, of which, 24 met the criteria for inclusion in this article (see Appendix S1). Eight references developed models of uncertainty from reviews of the literature,^{22,26,41-46} nine references from empirical research,^{8,14,47-53} and seven adapted existing models of uncertainty.^{31,54-59} The references that met the inclusion criteria explored uncertainty from the perspective of doctors,^{8,14,43,44,48,54} patients,^{22,45,49,51-53,57,59} carers,⁵⁵ medical students,^{46,50,56} a combination of healthcare providers and patients,^{26,41} healthcare,^{31,42,58} and policy.⁴⁷ All of the included conceptual models addressed one or more of the three dimensions of clinical uncertainty as defined in this paper: source, subjective influencers, and responses.

Sources of uncertainty were described in 20 conceptual models^{8,14,22,26,31,41-47,50-56,58} and are summarized in Appendix S1. Knowledge was described as a source of uncertainty in 18 models.^{8,14,22,26,31,41,43-47,50-52,54-56,58} Knowledge as a source of

uncertainty was represented by three categories: lack of knowledge, the nature of knowledge, and application of knowledge. Uncertainty derived from a lack of knowledge was identified in 16 models.^{8,14,22,26,43-47,50-52,54-56,58} The nature of knowledge was a source of uncertainty in five models.^{22,26,31,41,55} The nature of knowledge was characterized by the quality or type of information available. For example, information which results in uncertainty can be complex,^{22,26,31,41} ambiguous,^{22,26,41} or difficult to ascribe probabilities or interpret risk.^{22,26,41} Uncertainty which occurred as a result of applying knowledge was a source identified in eight models.^{8,22,43,46,50,51,54,56} For example, a doctor may be uncertain about tailoring management for a patient⁴³ or in how to apply abstract knowledge to clinical scenarios.^{8,54} Relationships were described as a source of uncertainty in 13 models.^{8,14,31,43,45-47,51-54,56,58} This uncertainty can stem from communicational issues between a doctor and patient⁵⁴ or interactions with other healthcare professionals.⁵² Systems were documented as a source of uncertainty in 12 models.^{14,22,26,42-47,54,55,58} For example, systemic uncertainty can arise due to differing practices and processes in complex healthcare settings^{46,58} or as a result of organizational culture.⁵⁴

Fifteen references contained models that identified subjective influencers of uncertainty.^{14,22,26,31,41,42,44,45,51-54,57-59} Three factors were identified: personal characteristics, experience, and affect (see Appendix S1). Personal characteristics were identified in all these fifteen references. These personal characteristics included three areas: personality,^{31,42,45,51,53} cognitive capacity,^{22,31,42,51,52} and worldview.^{26,31,41,44,52,54,57-59} For example, patients have reported that their personalities impact upon how they appraise medical uncertainty,⁵³ which can then impact on their desired level of involvement in care.⁵¹ The ability to process information, or cognitive capacity, can also influence how people interpret a source of uncertainty.²² The term 'worldview' covers the beliefs,^{26,41,44} values,^{41,58,59} and ethics^{54,58,59} unique to each individual, which may be independent or dependent on their cultural background.^{22,57} Uncertainty can arise when a person's worldview does not align with the values of the system that that person is operating in or those of other people involved.^{54,58} The experience that an individual brings to a situation, whether that is education,²² illness experience,^{22,53,57} or clinical experience,^{14,42} can influence how they perceive and respond to uncertainty. This was highlighted as a subjective influencer in seven models of uncertainty.^{14,22,42,44,52,53,57} Affect was identified in one model²² as a subjective influencer and was reported to impact uncertainty around symptom perception and to have an effect on cognitive state.

Responses to uncertainty were described in 14 models.^{14,22,26,31,45-49,51,53,54,56,57} Three response types were described: cognitive, emotional, and behavioural (see Appendix S1). Seven references described cognitive responses to uncertainty.^{14,22,31,47,49,51,57} Cognitive responses to uncertainty include acknowledgement of the presence of uncertainty^{31,47} and the perception of uncertainty as an opportunity or threat.^{22,31} Four references described emotional responses to uncertainty.^{14,22,31,54} Examples of

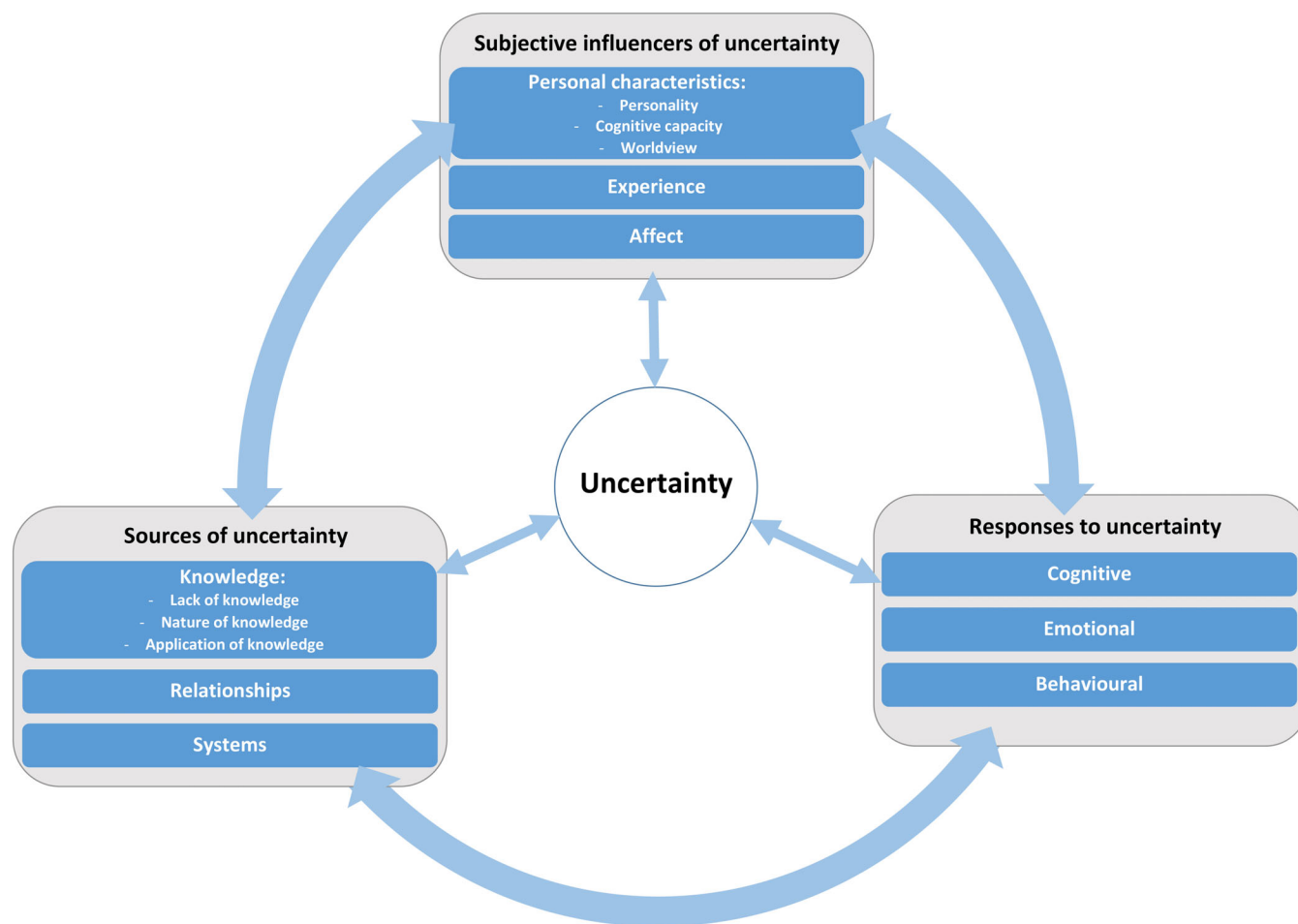


FIGURE 2 Framework for uncertainty in clinical practice

doctors' emotional responses to uncertainty include stress and anxiety.^{14,31,54} Patients too can struggle in their emotional responses to uncertainty and suffer stress.²² One reference³¹ noted that positive emotional responses such as hope or curiosity could arise from uncertainty. Eleven references described behavioural responses to uncertainty.^{14,22,26,31,45,46,48,49,53,54,56} Behavioural responses to uncertainty can be adaptive or maladaptive. For example, a doctor may excessively order diagnostic tests^{14,54} or make unnecessary referrals⁴⁶ as a response to uncertainty. Conversely, uncertainty may cause some doctors to innovate in difficult situations⁴⁸ and seek more information and expertise.⁵⁶ Patients, too, seek information as a way of coping with uncertainty.^{22,45,53}

Figure 2 illustrates a framework of clinical uncertainty constructed from the sources, subjective influencers, responses to uncertainty, and the dynamic relationship among these elements. The framework represents how uncertainty can arise as a result of knowledge, relationships, and the environments in which these relationships evolve. Personal characteristics, beliefs, and affect can influence how uncertainty is perceived and the subsequent response. Responses to clinical uncertainty can be cognitive, behavioural, and emotional. In the centre of Figure 2, uncertainty is defined as the dynamic, subjective perception of not knowing

what to think, feel, or do. This uncertainty can be perceived by a healthcare professional, a student, patient, or caregiver. The two-way arrows and circular design highlight the interrelated nature of the sources, influencers, and responses to uncertainty and also how each aspect impacts upon and is impacted by a person's uncertainty.

4 | DISCUSSION

A framework for uncertainty in clinical practice for use in medical education is proposed from the findings of a literature review of the existing models of uncertainty in healthcare. This framework is designed to aid medical students and educators in understanding a complex and constant phenomenon in their learning environments and breaks uncertainty down into sources, subjective influencers, and responses. The framework is novel in three important ways. First, it expands the aspects of knowledge included as sources of uncertainty. Second, it defines subjective influencers of uncertainty. Third, it highlights the dynamic relationships among sources of uncertainty, responses to uncertainty, and the individual factors that influence perceptions of uncertainty.

One way in which our framework for uncertainty in clinical practice adds to the literature is by illustrating the different aspects of knowledge that can be a source of uncertainty in healthcare. Our framework shows that uncertainty can stem not only from a lack of knowledge, but from the nature of that knowledge, and from difficulties applying that knowledge to real-life practice. A lack of knowledge causing uncertainty can arise from deficits on the part of the person involved or deficits in the knowledge that is available to them.^{8,30,43,50} For example, medical students might worry about their own level of knowledge⁵⁶ while doctors may lack access to evidence which would help to make a diagnosis or management plan.⁴³ Once a diagnosis or a treatment plan is made, uncertainty can arise due to inadequate knowledge of the skills or protocols required to proceed^{30,46} or the nature of information.^{22,26,41,58} Information relating to healthcare can be complex,^{22,26,31,41} ambiguous,^{22,26,31} and unpredictable.^{26,41,53} For example, a patient may feel uncertain when there is difficulty predicting the likelihood of recovery. The knowledge used to inform medical decisions is often based on statistical estimates, such as the accuracy of test results or the potential risks of a treatment or procedure. These estimates may be imprecise⁶⁰ or ambiguous²⁶ in their application to the decision at hand, resulting in statistical uncertainty.^{19,60} Doctors may become uncertain when presented with ambiguous or conflicting test results and not know how to describe that risk to their patients.²⁶ An awareness that statistics, whilst often a helpful means for reducing uncertainty, can also be an unavoidable source of uncertainty^{19,61} may help medical students to factor this into their decision making and communication with patients. Our framework of clinical uncertainty includes knowing how to distinguish between the different types of knowledge and how to apply it.^{8,50} This distinction is important when considering the difficulties that students or doctors might experience applying abstract criteria or knowledge to concrete situations.^{8,46,54} The inclusion of how knowledge acts as a source of uncertainty in our framework allows educators to be more focused on how they teach and students learn about this important aspect of uncertainty. For example, we may find that students feel uncertain about a clinical skill such as performing a cardiovascular examination, despite tutorials and simulation workshops. Educators can use our framework to understand that students' uncertainty might not stem from a lack of knowledge but from a difficulty in applying that knowledge in a real-world context. Consequently, educators can adapt their feedback to students to focus on applying knowledge to successfully perform that clinical skill rather than learning more about it.

By including these additional aspects of knowledge as a source of uncertainty, our framework highlights the complexity of the sources of uncertainty in clinical practice, especially when relationships and systems can also result in uncertainty. Healthcare is built on relationships that can, at times, themselves be a source of uncertainty, including the doctor-patient relationship^{8,26,43,46,58} and the relationships between healthcare professionals.^{26,30,47,58} Dealing with uncertain situations in healthcare does not happen in a vacuum,⁴³ and relationships are further complicated by the context and systems in which they take place.^{22,30,42,43,47,54,55,62} Patients may experience

uncertainty wondering about the standards of care that they might receive from a particular institution.²⁶ For doctors, systemic uncertainty could occur through availability of resources⁵⁴ or bureaucracy that impacts upon day-to-day work.⁴⁷ Our framework highlights how uncertainty can arise from knowledge, relationships, and systems and that these sources can occur in combination.

Our framework is novel in describing how each appraisal of uncertainty is impacted by influencers including personal characteristics (personality, cognitive capacity, and worldview), experience, and affect. These factors highlight the subjective nature of uncertainty and how it is constructed by both the doctor and patient based on their own experience and perceptions.²⁶ An individual's emotional or physical state can impact their capacity to perceive and respond to uncertainty.²² In the case of patients, this may be a result of illness;^{22,43} however, doctors are also subject to stressors and physical exhaustion as a result of their work, and affect may impact on their perceptions of uncertainty. For example, a recent study by Simpkin and colleagues⁶ showed that doctors who perceived uncertainty as a stressor were significantly more likely to suffer from burnout or depression. A vicious circle may develop with these emotional states in turn impacting upon how further situations of uncertainty are perceived. It has been suggested that uncertainty can result from a lack of knowledge and skills in acknowledging and managing affective states.³⁰ This is an example of how the interpretation of a subjective influencer of uncertainty can become a source of uncertainty, as highlighted by the cyclical nature of our framework. If we consider that each person involved in a clinical interaction, be that a doctor, patient, member of the healthcare team or student, will each have a unique set of subjective influencers that impact upon their perception of uncertainty, further complexity is added to situations of uncertainty. Our framework acknowledges the impact of these individual factors on how people recognize and respond to uncertainty and can be used by those designing educational strategies to help understand and mitigate stress from uncertainty in doctors or students.

Understanding subjective influencers may help to interpret why people respond to clinical uncertainty in the way that they do. Responses to uncertainty can be cognitive, emotional, or behavioural and can be positive or negative. Our framework highlights how sources of uncertainty and subjective influencers may impact upon responses to uncertainty, and how these responses may shape the ways in which sources of uncertainty are perceived. For example, a doctor who is inexperienced (subjective influencer) might lack the knowledge to manage a medical condition (source of uncertainty) and might deal with this by ordering unnecessary tests (behavioural response to uncertainty) or worry about outcomes (emotional response to uncertainty). If we wish to change this response to uncertainty, we need to start by understanding the dynamic relationships among sources of uncertainty, responses to uncertainty, and the subjective factors that influence perceptions of uncertainty.

Our framework can be used to consider existing teaching strategies developed to support medical students in their learning about clinical uncertainty. Healthcare professionals employ a range of strategies to manage clinical uncertainty, including the use of decision-



making aids such as guidelines and protocols,⁶³ evidence-based decision making,⁴³ clinical decision analysis,⁶⁴ and shared decision making.⁶⁵ Teaching tools to help medical students navigate uncertainty focus on cognitive and behavioural responses to uncertainty, primarily.^{66–74} Strategies to help medical students acknowledge uncertainty (cognitive response) include clinical simulation training⁶⁶ and online clinical vignettes⁶⁷ where there is no one correct way of managing a scenario. Acknowledging the presence of uncertainty in clinical practice has led to the development of examination questions that could replace single best answer questions.⁶⁸ Encouraging acknowledgement of uncertainty through self-reflection with the use of a reflective diary was found to help third-year medical students express and cope with their uncertainties about clinical practice.⁶⁹ Non-clinical interventions to help students cognitively respond to uncertainty include online decision-making scenarios⁷⁰ and an art-based module⁷¹ incorporating different ways of seeing and interpreting uncertainty. Focusing on cognitive responses to uncertainty means that other responses to uncertainty identified in our framework, behavioural, and emotional responses are not addressed in the above teaching methods. Teaching behavioural responses to uncertainty to medical students has focused on the communication of uncertainty.^{72,73} Medical students have been taught to navigate the inherent uncertainty in communicating risk to patients⁷² and how to communicate uncertain prognoses or diagnoses.⁷³ A case presentation strategy known as SNAPPS combines a cognitive and behavioural response to uncertainty. Here, students are encouraged to acknowledge uncertainty and then communicate uncertainties to colleagues.⁷⁴ These examples demonstrate that the teaching and learning strategies already in use to support students in their learning about uncertainty focus on only one dimension of uncertainty, responses to uncertainty. Our framework can be used to enhance and modify these teaching methods.

The use of our framework can help educators to appreciate that responses to uncertainty are in a dynamic relationship with the sources and subjective influencers of uncertainty. Our framework shows that relationships and systems can be a source of uncertainty in their own right. For example, a student who can successfully deal with uncertainty in a vignette or controlled simulation may struggle if faced with the same situation on a busy ward with an intimidating supervisor or distressed patient. The teaching strategies described in the preceding paragraph can be enhanced by acknowledging that subjective influencers can impact upon the perception of uncertainty. For example, a student may have previously tried and failed to communicate an uncertain diagnosis clearly to a patient. This previous experience may predispose the student to a behavioural response such as avoidance or emotional response such as fear. Emotional states such as fear or stress may in turn impact upon responses to uncertainty. For example, an anxious student presenting a case to a peer or senior may omit reporting uncertainties in order to appear more confident. It has been previously argued that knowledge- and competency-based assessments do not prepare medical students for a world of uncertainty.¹⁵ Educators could complement these assessments by using our framework to consider how other sources of uncertainty, such as relationships or issues in their learning environments, may be influencing

students. These examples show how our framework can be used by educators to identify and modify teaching strategies that address uncertainty and are relevant to situations that students will encounter in clinical practice.

Exploring medical research in the context of clinical uncertainty can be used as an example of how our framework could enhance teaching about a vital part of medical practice. A lack of knowledge is a major source of uncertainty in our framework, and medical research can be used to try and ameliorate this uncertainty when knowledge is lacking in a particular field.^{19,75} The choice of what type of research to conduct can be guided by underlying uncertainties.⁷⁶ Medical students are taught about the processes and utility of medical research, for example, when learning about how evidence-based medicine can inform treatment and prevent complications.⁷⁷ The results of research can still be subject to statistical uncertainty,^{19,60} which students and healthcare providers must be able to understand and convey clearly to patients to provide high-quality care.⁷⁷ Our framework also suggests that if medical students cannot apply this new knowledge and communicate it clearly, further uncertainty may ensue. Educators could therefore address multiple sources of uncertainty by teaching students how to interpret and apply the results of medical research in their practice. The dimension of subjective influencers of uncertainty described in our framework also illustrates the difficulties of applying the results of large-scale research to individual care, an issue that has been observed in evidence-based medicine.⁷⁷ For example, a patient's prior experiences or personality may cause them to feel uncertain about a management plan based on the latest research, despite the risks and benefits being clearly described. Recommendations stemming from medical research may not align with a doctor or patient's worldview and, as a result, intensify uncertainty, rather than alleviate it. An understanding of this dimension of uncertainty could be used to help medical students learn to personalize patient care by incorporating the best available evidence alongside an appreciation of individual patient needs. As discussed previously, a void can exist between medical research and its application no matter how well done the research. Educators can use our framework to help explain to students why this void exists and how uncertainty persists even 'when there is so much science'.⁷⁸ (p. 7)

The strengths of this framework lie in the recognition of all of the sources, subjective influencers, and responses to uncertainty and the dynamic interaction between these dimensions. The omnipresence of uncertainty in healthcare would mean that trying to identify every single context-specific source or response to uncertainty would be an impossible task. The subsections of our framework are broad enough to capture this and act as an aide memoir when considering the teaching and learning about uncertainty. To teach effectively about a medical condition, we need to first understand all aspects of that condition. For example, to understand pneumonia, a student requires knowledge on anatomy, physiology, pathophysiology, epidemiology, and treatment strategies. This approach is also needed when teaching and learning about clinical uncertainty. By breaking clinical uncertainty down into three dimensions, sources, subjective influencers, and responses, our framework

attempts to bring current knowledge and thinking together in a way that will be useful for those who wish to explore uncertainty with medical trainees and help educate their students on uncertainty in clinical practice. As has been recently argued in this journal,³⁵ there is no one-size-fits-all conceptual model for uncertainty. We can, however, tailor a model for a particular purpose—in this case, education. Our framework is strengthened by the fact that it has been built using literature which addresses student, doctor, patient, and carer perspectives. By bringing the concepts and ideas from the models included in this paper together using the framework in Figure 2, we have a comprehensive picture of clinical uncertainty that is evidence based and adaptable to educators' needs.

This study does have several limitations. The search terms chosen and use of multiple databases meant that the search strategy was focused on medical specialities predominantly and at the expense of examining models of uncertainty in other health professions such as pharmacy and physiotherapy. In restricting the search strategy to references in the English language, at least one potential reference was excluded.⁷⁹ As the inclusion criteria also included only references that presented models of uncertainty, other aspects of the literature that explore doctors' and students' perspectives on uncertainty were excluded. For example, it would be fascinating to see whether the framework presented here is applicable to this literature, especially qualitative studies where students' perspectives on uncertainty have been explored (such as the work on reflective learning diaries mentioned previously).⁶⁹ The definition of uncertainty proposed in this paper formed the theoretical framework for analysing the conceptual models included in this study. Whilst broad, this definition may not be sufficient to capture all nuances of uncertainty in other areas which differ from medical education.

Potential future directions for the framework presented in this paper include the development of instruments to explore how medical students might interpret or respond to sources of uncertainty in their learning environments. This framework could also be used to evaluate curricula, learning environments, or teams and to identify places where teaching opportunities about uncertainty could occur. This framework could be used to help design learning resources to support students' learning about uncertainty at different stages of their medical training. We have already used this framework to develop a teaching and learning tool which will be trialled with medical students and doctors in the future.

5 | CONCLUSION

A framework of clinical uncertainty designed for education has been developed following a review and synthesis of models of uncertainty in healthcare. This framework aims to be comprehensive and clearly comprehensible. It has been designed to aid educators and students to interpret and navigate clinical uncertainty in its multiplicity of aspects. The framework highlights the dynamic nature of uncertainty and represents uncertainty as sources, subjective influencers, and responses to uncertainty. By understanding these dimensions of

uncertainty, we can enhance our understanding and teaching of a concept which will form a part of every doctor and patient's journey. It may also enhance the possibility to see uncertainty as an opportunity for learning and innovation. Even though uncertainty can be experienced as the dynamic subjective perception of not knowing what to think feel or do, it does not mean that uncertainty it is something for medical students and educators to fear.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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