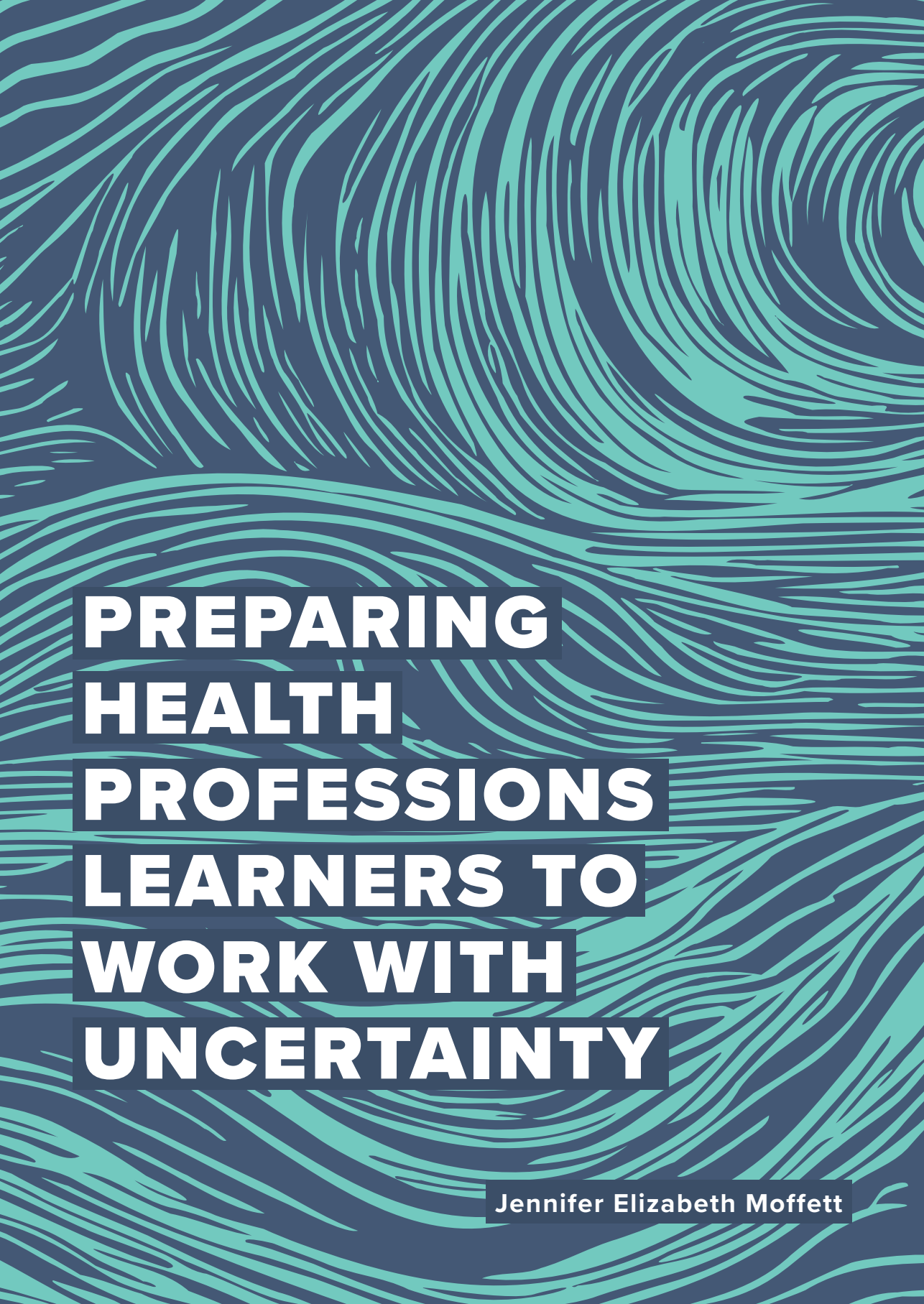
PREPARING HEALTH PROFESSIONS LEARNERS TO WORK WITH UNCERTAINTY
Jennifer Elizabeth Moffett

Preparing health professions learners to work with uncertainty

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The research described in this thesis was financially supported by:
Irish Network of Healthcare Educators/ Medical Council of Ireland Research in Medical Education Grant
RCSI Student Engagement and Partnership (StEP) Initiative
RCSI Staff Development Fund

ISBN: 978-94-6496-162-1
DOI: https://doi.org/10.33540/2385

Cover: Ilse Modder | www.ilsemodder.nl
Lay-out: Ilse Modder | www.ilsemodder.nl
Printing: Gildeprint Enschede | www.gildeprint.nl

Preparing health professions learners to work with uncertainty

Het voorbereiden van gezondheidszorgstudenten op het omgaan met onzekerheid (met samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof. dr. H.R.B.M. Kummeling, ingevolge het besluit van het College voor Promoties in het openbaar te verdedigen op woensdag 11 september 2024 des middags te 12.15 uur

door

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geboren op 20 oktober 1976
te Birmingham, Verenigd Koninkrijk

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Introduction

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HEALTH PROFESSIONS EDUCATION AND UNCERTAINTY

The experience of uncertainty is commonplace for healthcare professionals who must navigate a workplace replete with incomplete, ambiguous, conflicting, and complex information. Each day, they are required to make decisions and push forward with patient care, despite lacking clear or complete data. There are many features of modern medicine that accentuate clinical uncertainty, including the rapid expansion of scientific knowledge, technological advances in diagnostic and therapeutic procedures, an aging population with complex needs, and a more internationally mobile workforce. Add to this the disruption of a global pandemic, and it is clear that uncertainty and its management is a salient topic for healthcare professionals[1].

Healthcare uncertainty has been studied for many decades by researchers from diverse perspectives including medicine, philosophy, psychology and sociology[2]. However, the question of how best to prepare healthcare professionals to manage uncertainty remains unanswered, with few clear-cut guidelines for institutions or educational developers. Indeed, training students for uncertainty has been called medical education's "most elusive ideal"[3(p.70)].

The research presented in this thesis aims to explore the topic of uncertainty within health professions education, and how learning around this important topic can be facilitated. In this introductory chapter, we provide an overview of uncertainty and how it impacts healthcare professionals. We also examine the role of health professions education in supporting learners to build constructive approaches towards uncertainty. Finally, we set out the problem definitions and research questions that this thesis seeks to address, concluding with an outline of the thesis itself.

IMPACT ON HEALTHCARE PROFESSIONALS

To understand uncertainty within the healthcare context, it may be useful to consider a typical clinical scenario. If we imagine a case where a veterinarian is working with a client whose elderly cat has rapidly lost weight. The veterinarian knows that there may be multiple reasons for this, and that different tests exist can narrow down the differential diagnosis. Although the veterinarian will have some ideas on what test to choose first, she does not have full insight into the client's values, beliefs and emotions, nor her socio-economic background, all of which may impact on treatment options. This situation typifies the uncertainty that arises from patient care, where decisions extend beyond the scope of textbooks or standard protocols. If we now imagine that the client agrees to blood tests for her cat, this may provide extra data and reduce some of the uncertainty of the situation.

However, if the test results are suggestive of multiple disease processes, or none at all, this adds further ambiguity. Moreover, even if blood tests suggest a clear path forward, e.g., a diagnosis of hyperthyroidism, there is no guarantee that the chosen medication will improve the cat's clinical signs. This represents yet another uncertainty present in clinical care, the unpredictability of healthcare outcomes (i.e., patients may or may not respond to treatments, and disease processes may advance quickly or not at all.)

Over the last seventy years, different scholars have attempted to analyse such instances of healthcare uncertainty, how they arise, who they affect and what should be done to address them[4-7]. However, these efforts have been hampered by "the absence of a shared concept of uncertainty, and a lack of integration of insights from different disciplines"[8(p..2)]. Whilst there is no agreed upon definition of uncertainty in the healthcare literature, it is frequently conceptualised as a "subjective perception of not knowing what to think or what to do"[9(p.3)]. This notion of uncertainty as a metacognitive state or a conscious awareness of ignorance is expanded on by researcher Paul Han[10(p.4)], who says: "Uncertainty is ultimately a subjective rather than an objective phenomenon, a mental state rather than a material thing residing in the experimental world. It lies entirely in the eye and mind of the beholder." This idea of uncertainty as an individualised experience can be observed in contemporary heuristic frameworks such as Han and colleagues' (2011) taxonomy[8], which characterises healthcare uncertainty according to its sources (i.e., where the uncertainty emerges from), issues (i.e., what the uncertainty can lead to), and locus (i.e., to whom this uncertainty relates). Contemporary thinking around healthcare uncertainty is that it is a phenomenon which is multifaceted, dynamic, and ever-present within clinical and professional practice[11,12].

In exploring how healthcare professionals respond to uncertainty, the literature is sporadic and unstructured, encompassing a wide diversity of study methodologies and psychometric constructs (e.g., uncertainty tolerance, uncertainty intolerance, ambiguity tolerance, and ambiguity intolerance)[12-14]. This body of research tends to focus on the idea that certain individuals are better at managing or "tolerating" uncertainty than others. Hillen et al.[11(p.70)] offer a helpful definition of uncertainty tolerance as "the set of negative and positive psychological responses – cognitive, emotional, and behavioural - – provoked by the conscious awareness of ignorance about particular aspects of the world." Studies suggest that uncertainty tolerance may be linked to important outcomes for healthcare professionals. For example, medical students who are more comfortable with uncertainty may be drawn to careers such as psychiatry, internal medicine or general practice[15-17] whilst those who are less comfortable may prefer disciplines such as surgery or radiology[15,16]. Other studies that explore clinical skills suggest that physicians who are less tolerant of uncertainty may be more likely to reach diagnoses prematurely[18], engage in poor decision making[19], over-order tests, and over-prescribe medications[20]. Furthermore, studies suggest a link between low uncertainty tolerance and reduced psychological well-being for medical students and doctors alike[21].

Although such research implies that medical professionals will always benefit from a high tolerance of uncertainty, it should also be noted that a potential "flip side" exists. For example, Reis-Dennis and colleagues[2(p.2412)] suggest that medical professionals with overtly high uncertainty tolerance may leave a patient for too long without the correct medical attention, highlighting that "both tolerance and intolerance of uncertainty can give physicians advantages while at the same time exposing them to pitfalls in clinical practice."

THE ROLE OF HEALTH PROFESSIONS' EDUCATION IN SUPPORTING LEARNERS TO MANAGE UNCERTAINTY

Despite wide acceptance that uncertainty is inherent within healthcare practice, and has an important impact on health professionals' work, the topic is surprisingly overlooked within health professions education. Authors have labelled uncertainty and ambiguity as "neglected elements of medical curricula"[22(p.799)], and have accused professions of failing to prepare graduates adequately[23].

Whilst it appears that uncertainty and preparing students to manage it are issues for many modern professions[24], authors have suggested specific reasons for this prominent gap within health professions curricula. For example, it has been prosed that uncertainty is "generally suppressed and ignored, consciously and subconsciously" within medicine[25(p.1713)], meaning that there may be a reluctance to address what is seen as a difficult or uncomfortable topic. Furthermore, a lack of guidance on how to train for uncertainty may leave health professions educators feeling ill-equipped to approach the topic with their students. This curricular gap is not, however, related to a lack of perceived need. A study of Finnish medical students highlighted that 22% felt that they had difficulty tolerating uncertainty when making medical decisions[17]. Furthermore, a study of Irish medical students reported that 27% experienced psychological distress that could be linked to uncertainty intolerance[26].

There is, however, cause for optimism in that a renewed interest in preparing students to cope with increasingly complex and uncertain clinical landscapes has emerged. This is evidenced by the appearance of uncertainty and related competencies within a wide diversity of professional frameworks. Examples include:

- CanMEDS Physician Competency Framework (2015)[27(p.4)]: "[Physicians are able to…] recognize and respond to the complexity, uncertainty, and ambiguity inherent in medical practice."
- General Medical Council Outcomes for Graduates (2018)[28(p.11)]: "The nature of illness is complex and therefore the health and care of many patients is complicated and uncertain. Newly qualified doctors must be able to recognise complexity and uncertainty. And, through the process of seeking support

and help from colleagues, learn to develop confidence in managing these situations and responding to change."

- National Competency Framework for pharmacists in Thailand (2020)[29(p.8)]: "Self-management skills: Demonstrate flexibility and adaptability in uncertain situations."
- Royal College of Veterinary Surgeons Day One Competences (2022)[30(p.11)]: "Act professionally in complex situations. This could be situations where there is ambiguity and/or uncertainty, where there may be no clear diagnoses."

Although these additions herald a shift in mindset, research into how to develop skills in managing uncertainty has lagged. Current thinking suggests that students and qualified health professionals build approaches to uncertainty as their education and career progresses[31], but there is little information on how or where this development takes place. Some authors propose a socialisation or maturation process[16,32] . Others suggest that teaching approaches such as mentoring[23], clinical clerkships[33] and reflective practice[34] play a role. A recent scoping review by Patel et al.[35] also highlights that strategies such as problem-based learning, medical humanities, simulation, reflection and assessment may have a positive influence on medical students' uncertainty tolerance. Such work is important as it supports the conceptualisation of uncertainty tolerance as something that can be nurtured and developed[36], rather than something immutable and personality-dependent[15]. Thus whilst evidence is building that education interventions have the potential to develop health professions learners' uncertainty management skills, it is clear that more work is required to understand relevant learning environments at a more granular level.

SUMMARY OF PROBLEM DEFINITIONS AND RESEARCH QUESTIONS

THESIS AIM

The overall aim of this thesis is to explore how health professions students learn to manage uncertainty during their undergraduate training. More specifically, we wanted to examine existing epistemic evidence and the lived experience of healthcare educators and students so as to inform an educational solution that could facilitate medical students' learning in this domain. To achieve this aim, we chose a design-based research (DBR) approach. DBR is "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings"[37(p.6)]. This approach was deemed most appropriate to our ambitions since DBR "strives toward two main goals, simultaneously: advancing theoretical understanding and development of an intervention in the real world"[38(p.2)]. Thus, DBR would allow us to probe existing questions about how contemporary

medical curricula prepare students to manage uncertainty, whilst also developing a practical way of facilitating effective learning in this domain.

Design-based research involves a process with phases of analysis/exploration, design/construction and evaluation/reflection[38] (see Figure 1). In the case of our research, we aimed to build foundational knowledge around the topic of uncertainty in health professions education, before moving into cycles of "design and refine" with respect to an educational solution. This process resulted in the development of an intervention to be used in a real-world medical education setting, whilst also advancing theoretical knowledge (e.g., through developing design principles which could guide researchers and practitioners working in related educational contexts).

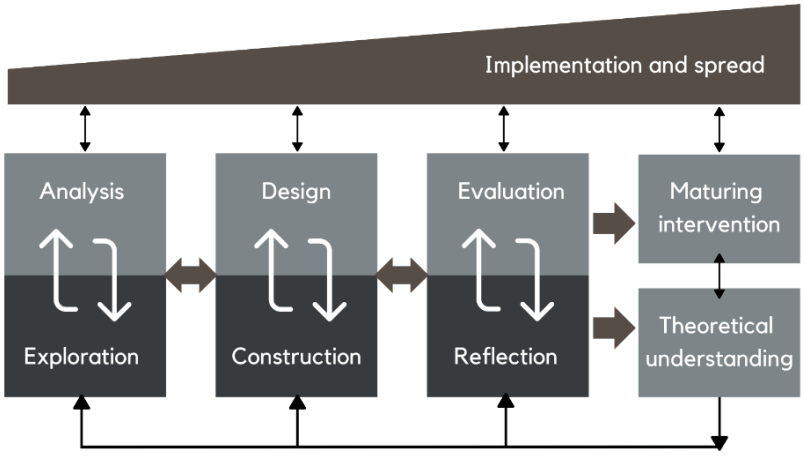

Figure 1: Core phases of design-based research (McKenney & Reeves, 2018)

THEORETICAL FRAMEWORKS

DBR has a multifaceted relationship with theoretical understanding in that it "underpins the design of an intervention, frames the scientific inquiry and is advanced by findings generated through empirical testing of the intervention"[38(p.18)]. Over the course of our research, two theoretical frameworks both contributed to the data, and underwent interrogation and analysis. The first of these was Han et al.'s (2011) taxonomy of uncertainty[8] (Figure 2). As mentioned previously, this conceptual model aims to characterise healthcare uncertainty according to three dimensions, i.e., the sources, issues, and loci of uncertainty. An example of this is a doctor (locus of uncertainty) who requests a set of patient notes but finds that these are incomplete (source of uncertainty), causing a barrier for her in proposing a treatment plan (issue of uncertainty). We selected this taxonomy as a theoretical framework

as it was well-established within the healthcare literature[39-43] and provided a valuable way to analyse and "exteriorise" the nuances of uncertainty experiences. Within the context of our research, the taxonomy was used to gain clearer insight as to the dynamic and multi-dimensional nature of uncertainty, whilst also examining its utility within novel educational contexts.

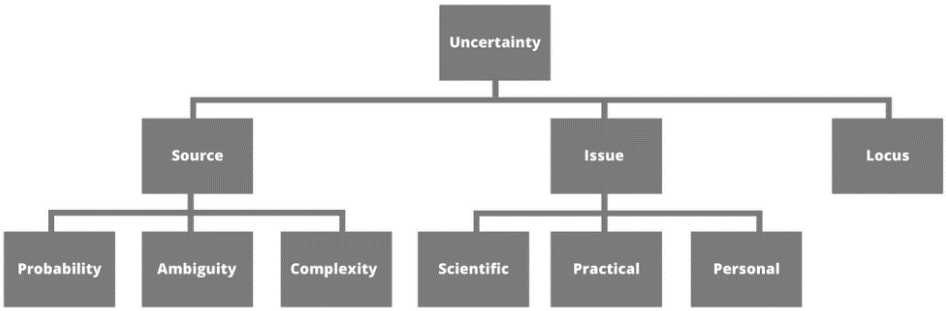

Figure 2: Han et al.'s (2011) taxonomy of uncertainty

The second theoretical framework used in this research was Community of Inquiry (CoI)[44] (Figure 3).

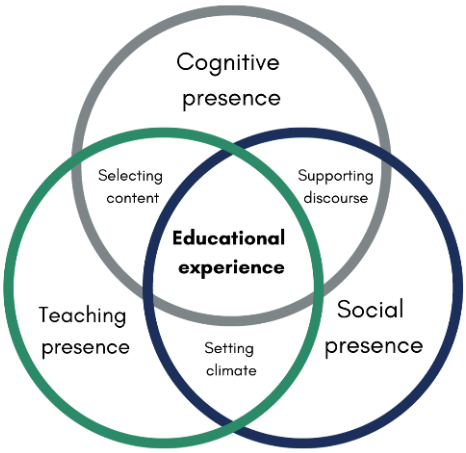

Figure 3: The Community of Inquiry framework (Garrison et al., 2010)

The CoI model is a widely recognised framework in the domain of online learning which describes "a process of creating a deep and meaningful (collaborative-constructivist) learning experience through the development of three interdependent elements – social, cognitive, and teaching presence"[45]. We adopted this model as a means of identifying and analysing the interactions and mechanisms which facilitate learning in virtual and online environments. CoI highlights core elements that can cultivate effective online learning environments, such as facilitating peer-peer and peer-tutor interactions and offering engaging cognitive activities. Our research used Community of Inquiry to ground our design work, whilst also extending existing knowledge around how to apply this model in online learning environments.

RESEARCH QUESTIONS

Our DBR project involved multiple phases and studies, ultimately leading to several different research questions.

The first, or "analysis/exploration," phase of our research sought to establish foundational knowledge around uncertainty and how health professions education might facilitate learning in this domain. This phase centred on two opening research questions:

- How do undergraduate health professions students learn to engage with uncertainty related to their academic practice?
- What attributes might help undergraduate health professions students to manage uncertainty?

The second, or "design/construction," phase involved the development of a proposed solution, an educational escape room, through an iterative process of designing and testing prototypes. This led to a third research question:

- What are medical students' experiences of building and playing a digital educational escape room developed using an online design-thinking process?

In the third and final phase, "evaluation/reflection," we investigated the early stages of the implementation of our educational solution, and reflected on the impact of our research on both theory and practice. This led to two final research questions:

- How can a digital educational escape room be used to facilitate learning around managing uncertainty for undergraduate medical students?
- What can we learn from applying Community of Inquiry to an escape room learning environment?

THESIS OUTLINE

In this thesis, Chapter 2 reports on a scoping review that aims to provide a "map" of what is already known with respect to how undergraduate health professions students learn to engage with uncertainty. The review employs a search strategy that examines several journal databases and health professions education journals in order to reveal the nature and extent of the existing literature within this domain. Chapter 2 addresses the first research question of this thesis.

Chapter 3 reports on a study that explores the use of a recognised taxonomy of uncertainty[7] (Han et al., 2011) within an educational workshop setting. The aim of the workshop is to help "unpack" examples of student uncertainty and identify attributes (i.e., knowledge, skills, and attitudes) which may be useful to undergraduate health professions' learners in managing uncertainty. This chapter addresses the second research question.

The findings from the opening two chapters feed into a third study, one that outlines the design, build and evaluation of an educational resource known as a digital educational escape room (DEER). Chapter 4 provides a detailed description of how the DEER was developed and tested through an online design-thinking process. Chapter 5 reports on the game-building process itself, and the experiences of student design team members, as viewed through the lens of psychological safety[46]. Both chapters contribute to the third research question.

Chapter 6 reports on an early implementation of the escape room, using CoI as a model to understand how learning takes place. This chapter culminates with a proposition of design principles for DEERs, and addresses the fourth and fifth research questions. Finally, Chapter 7 harnesses the overall research findings in order to offer practitioner recommendations for the design and build of DEERs.

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The ubiquity of uncertainty: a scoping review on how undergraduate health professions' students engage with uncertainty

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Published in: Advances in Health Sciences Education, 26(3): 913–958.

2

ABSTRACT

Although the evidence base around uncertainty and education has expanded in recent years, a lack of clarity around conceptual terms and a heterogeneity of study designs means that this landscape remains indistinct. This scoping review explores how undergraduate health professions' students learn to engage with uncertainty related to their academic practice. To our knowledge, this is the first scoping review that examines teaching and learning related to uncertainty across multiple health professions. The scoping review is underpinned by the five-stage framework of Arksey and O'Malley (2005).

We searched MEDLINE, Embase, PsychINFO, ISI Web of Science, and CINAHL and hand-searched selected health professions' education journals. The search strategy yielded a total of 5,017 articles, of which 97 were included in the final review. Four major themes were identified: "Learners' interactions with uncertainty"; "Factors that influence learner experiences"; "Educational outcomes"; and, "Teaching and learning approaches".

Our findings highlight that uncertainty is a ubiquitous concern in health professions' education, with students experiencing different forms of uncertainty at many stages of their training. These experiences are influenced by both individual and system-related factors. Formal teaching strategies that directly support learning around uncertainty were infrequent, and included arts-based teaching, and clinical case presentations. Students also met with uncertainty indirectly through problem-based learning, clinical teaching, humanities teaching, simulation, team-based learning, small group learning, tactical games, online discussion of anatomy topics, and virtual patients. Reflection and reflective practice are also mentioned as strategies within the literature.

INTRODUCTION

Health professionals regularly encounter uncertainty in their work, experiencing "a subjective perception of not knowing what to think or what to do"[1(p.3)]. Indeed, it is accepted that uncertainty is "normal, understandable, and to be expected in professional practice"[2(p.53)]. When confronted with complex or ambiguous situations, individuals react in different ways, often framed in terms of their cognitive, emotional and behavioural response[3,4]. These differences, and the capacity of health professionals to manage uncertainty overall, are often referred to as "uncertainty tolerance." Studies, largely in medicine, have found that professionals' capacity to manage uncertainty is important with respect to their career choices[5-7], attitudes to patients[5,8], clinical decision-making skills[4,5], and exposure to work-related stress[9-13]. Furthermore, a professionals' capacity to work with uncertainty has been linked to positive outcomes for others, e.g. greater patient satisfaction[14,15] and decreased medical errors[16,17]. A recent review by Strout and colleagues[5] highlighted a strong, consistent association between health professionals' uncertainty tolerance, and their patients' emotional well-being. This growing evidence base has encouraged the addition of uncertainty management competences to many regulatory professional frameworks[18-21].

Considering this increasing research interest, relatively less attention has been paid to how health professions' learners build this capacity to work with uncertainty. Existing studies point to a long-standing balancing act between the overarching human preference for certainty and the uncertain nature of real-world patient care[22-27]. Authors suggest that we have consistently failed to bridge the gap between the two, labeling training for uncertainty as medical education's "most elusive ideal"[28(p.70)]. This contributes to an educational climate which "rewards those who give correct answers, and often denigrates learners who admit uncertainty"[29(p.523)].

It has also been argued that health professions' education may have come adrift with regards to preparing learners for the "messiness and unpredictability" of professional practice[30(p.145)]. Wear[31(p.1500)] hypothesises that the "rapid shift over the past decade to a technology-driven, competency-oriented environment" may mean that learners have less opportunity to develop "responsiveness to an evolving human situation in a clinical context." Indeed, could our modern curricula, "bloated with required lectures and courses, with insufficient time for independent thought and elective study", lie at the heart of the problem? [28(p.70)].

Authors have recommended specific ways to facilitate learning around uncertainty, from humanities teaching, small group approaches, and simulation[32-37], through to faculty development[38,39]. Taken as a whole, however, little is known about how health professions' programmes "intentionally and systematically" teach students to manage uncertainty[40(p.32)]. This leaves educators in a position where they are asked to support learning around

uncertainty, but with little clear advice on how best to do this[35,36,41].

Although the evidence base around uncertainty and education has expanded in recent years, a lack of clarity around conceptual terms and a heterogeneity of study designs means that this landscape remains indistinct, replete with "fuzzy" boundaries[4,42,43]. This hinders educators' ability to prepare health professions' learners to work with the uncertainty inherent in their day-to-day work. The authors considered that the existing literature could be usefully "mapped", making what we know so far in relation to uncertainty and education more accessible. Our aim was to explore how learners from a range of different health professions begin to learn about uncertainty within the context of their education. As our interest extended across multiple professions, we decided to focus on findings related to undergraduate health professions learners' as these may be more broadly comparable. We chose a scoping review approach to provide an overview of this emergent evidence base. This was considered an appropriate methodology which could help us unravel what research exists, and what characteristics or factors are important when considering uncertainty in health professions' education[44]. To our knowledge, this is the first scoping review that examines teaching and learning related to uncertainty across multiple health professions.

METHODS

We followed the scoping review framework described by Arksey and O'Malley[45], and incorporated guidance by Peters and colleagues[46]. The five steps of the framework were: 1) identifying the research question, (2) identifying relevant studies, (3) selection of relevant studies, (4) charting the data, and (5) collating, summarising and reporting the results. In addition, we used the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) to guide reporting of the study[47].

STAGE 1: IDENTIFYING THE REVIEW QUESTION

Following a pilot search, we decided to focus on how undergraduate health professions' learners both experience and respond to uncertain situations. The final wording for the research question was: "How do undergraduate health professions' students learn to engage with uncertainty related to their academic practice?" We adopted a broad definition which framed uncertainty as a "subjective perception of ignorance that is experienced by health professionals in differing ways and degrees, motivates action, and elicits a variety of psychological responses" (adapted from Han and colleagues[26]). Our focus on undergraduate learners took into consideration the different models and approaches to health professions' education which exist[48]. Thus, we were interested in studies which related to students enrolled on health professions-specific, college-level courses which would lead to registration to practise in their chosen profession. Finally, we chose the verb

"engage", so as to capture both learners' experiences of, and responses to, uncertainty, as these were both deemed of interest.

STAGE 2: IDENTIFYING RELEVANT STUDIES

We devised the search strategy in consultation with an academic librarian through an iterative process using both keywords and Medical Subject Headings (MeSH) terms. Due to conceptual overlap between uncertainty and ambiguity, which was evident in the literature and within our pilot search, both terms were included in the search[42,43,49].

We searched MEDLINE, Embase, PsychINFO, ISI Web of Science, and CINAHL. In addition, we carried out a hand search of 14 health professions' education journals, and completed a backward citation search of all articles that met the review criteria. We limited all strands of the search to studies published from January 1, 1950 until September 14, 2020.

STAGE 3: SELECTION OF RELEVANT STUDIES

We used EndNote X7.8 (Thomson Reuters, USA) to import and organise the citations of articles yielded from the search strategy. Initially, articles were grouped according to their source, and duplicate citations were removed. Researchers JM and JH independently reviewed a group of 50 studies in tranches to pilot the initial eligibility criteria, and make any necessary refinements. Studies were included in this review on the basis of an agreed set of inclusion and exclusion criteria (Table 1). JM and JH independently screened titles and abstracts of the studies to identify those eligible for full-text review. A third researcher (TP) was consulted on disagreements until consensus was attained (Figure 1). All studies deemed relevant were submitted for full-text screening. Again, JM and JH independently screened studies, with TP facilitating consensus.

Table 1: The ubiquity of uncertainty: a scoping review on how health professions' students engage with uncertainty: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Articles were included in this scoping review if they: • Were published in English • Related to undergraduate health professions' students (limited to medicine, nursing, midwifery, dentistry, veterinary medicine, physical therapy and/or physiotherapy, pharmacy students) • Focused to uncertainty in the context of the individual's professional practice • Focused on teaching and learning as reported by student rather than other stakeholders • Described empirical research (i.e., represented a peer-reviewed article with overt data collection)	Articles were excluded from this scoping review if they: • Related to postgraduate education or continuing professional development • Focused on teaching and learning from the perspective of the educator or patient, or from broader paradigms e.g., educational development • Were books, commentaries, conference abstracts, editorials, letters, opinion papers, or unpublished theses

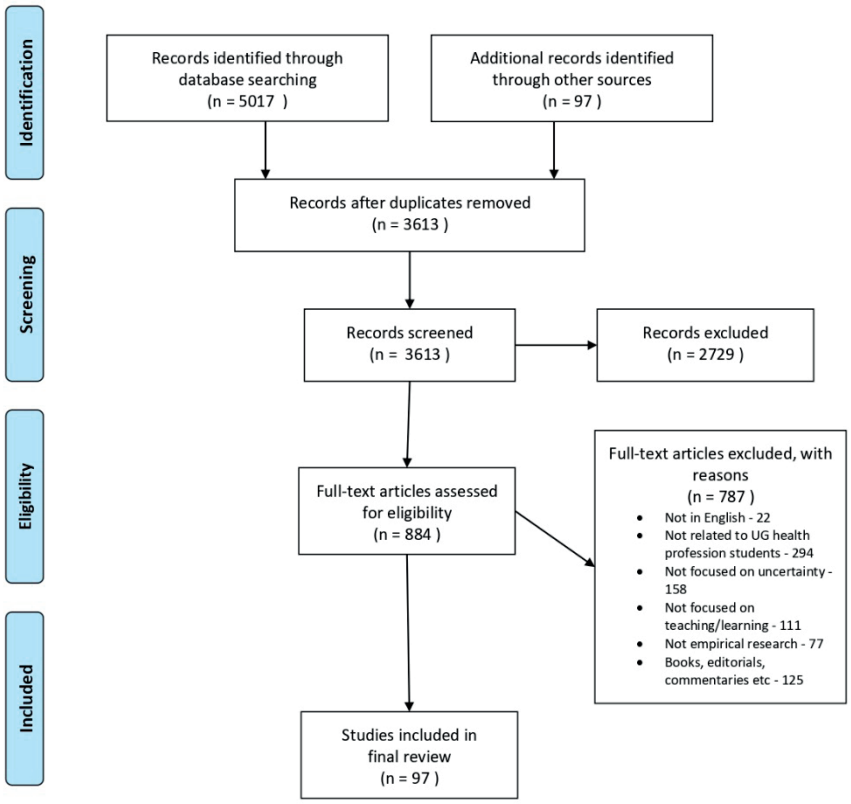

Figure 1: PRISMA Scr

STAGE 4: CHARTING THE DATA

Data extraction followed an iterative process, and a template was used to extract the following information: publication details (authors, publishing year, title of journal and paper), country of origin, study design, study population, research outcome(s), type and description of intervention, if any, as well as key findings that related to the research question. We used a combination of Microsoft Excel and Forms (Microsoft, USA) to extract the data, with the characteristics of the full-text articles extracted independently by JM and JH. Studies were excluded at this stage if they did not meet eligibility criteria. Discrepancies were solved through re-reading and discussing studies in consultation with TP.

STAGE 5: COLLATING, SUMMARISING AND REPORTING THE RESULTS

We used a narrative approach to thematically synthesise the data[50]; JM and JH identified initial themes within the studies. These were shared, mapped and discussed iteratively, which helped visualisation of the data and recognition of connections between themes. The third researcher (TP) addressed any discrepancies to ensure consensus was reached.

RESULTS

CHARACTERISTICS OF INCLUDED STUDIES

The search strategy yielded a total of 5,017 articles, of which 97 articles were included in the final review (Figure 1).

Of these studies, half had been published within the last five years (50%, n=48), with the USA the most frequently reported location (35%, n=34), followed by the UK (20%, n=19), and Canada (11%, n=11). Studies described both uniprofessional (90%, n=87) and multiprofessional (10%, n=10) student cohorts. The most commonly represented students were medical (65%, n= 63), followed by nursing (25%, n=24). Studies were more likely to describe qualitative research (57%, n=55), than quantitative (32%, n=31), or mixed method approaches (11%, n=11). A summary of the final study characteristics is presented in Table 2.

IDENTIFIED THEMES AND SUB-THEMES

Four major themes were identified: "Learners' interactions with uncertainty"; "Factors that influence learner experiences"; "Educational outcomes"; and, "Teaching and learning approaches."

Learners' interactions with uncertainty

Types of learners

A wide variety of health professions' learners meet uncertainty within the context of their undergraduate studies. The vast majority of studies reported on cohorts of medical and nursing students; however, experiences of uncertainty were also recorded within midwifery, physiotherapy, veterinary, dentistry and pharmacy student cohorts[32,51-60]. Studies included learners at all stages of their undergraduate training.

Types of uncertainty

Learners' experiences of uncertainty, could be categorised as: (i) uncertainty related to the practice of healthcare itself[62-69]; (ii) uncertainty related to the educational process[54,70-76]; and (iii) uncertainty related to the learner's self[54,57,65,66,68,76-81]. Uncertainty emerged when learners experienced differences between themselves and others[82-87], unfamiliar situations, or issues lacking easily distinguishable solutions[76,82-84,88-90]. Common places where this happened were at transitions (e.g., entry into undergraduate studies, movement into, and between, clinical placements)[56,71,91,92], and in specific environments such as problem-based learning[55,74,93], and clinical settings[58,71,72,94-96]. Several studies commented on how the types of uncertainty that learners experienced, and their concerns around these, evolved as they progressed through their education[63,97]. Finally, the uncertainties faced by students in the context of the global coronavirus pandemic began to emerge in studies published in 2020[59,98].

Table 2: Summary of main characteristics of the final studies

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Ali, MA et al.	2017	Canada	Multiprofessional	6	Nursing students; Students from other professions	Qualitative	Interviews; Focus groups	Field placements/ Clinical internships
Al-Kloub, M et al.	2019	Jordan	Uniprofessional	130	Third-year medical students	Mixed methods	Questionnaire (PBL Evaluation Questionnaire); Observation (daily logs)	Problem-based learning
Balentine, CJ et al.	2010	USA	Uniprofessional	236	Medical students	Quantitative	Questionnaire (Patient Provider Orientation Scale, Physician Reaction to Uncertainty)	N/A
Bassett, AM et al.	2015	UK	Uniprofessional	26	Nursing students (mental health)	Qualitative	Interviews	Clinical setting
Bentwich, ME et al.	2017	Israel	Uniprofessional	67	First-year medical students	Quantitative	Questionnaire (open and closed questions)	Visual thinking strategies (arts-based learning)
Biley, F & Smith, K	1999	UK	Uniprofessional	17	Nursing students	Qualitative	Interviews; Observation data	Problem-based learning
Bing-You, R	1991	USA	Uniprofessional	47	Medical students	Quantitative	Questionnaire (Scott's Value Scale, Webster's Authoritarian Scale)	Clinical clerkships
Bintley, HL et al.	2019	UK	Uniprofessional	40	Medical students	Mixed methods	Examination performance; Focus groups	Simulation-based learning
Brondani, M & Donnelly, L	2020	Canada	Uniprofessional	115	Dentistry students	Qualitative	Observation data (reflective writing)	Reflection
Carr, S et al.	2001	UK	Uniprofessional	nc	Nursing students; Educators	Qualitative	Interviews; Focus Groups; Observation data (practice narratives)	Practice experience of nursing in a clinical community context
Chan, EA & Nyback, MH	2015	Finland / China (Hong Kong)	Uniprofessional	20	First-year nursing students	Qualitative	Observation data (student projects, reflective writing)	Technology-enhanced learning (online cultural competence course)
Curtis, K	2014	UK	Uniprofessional	19	Nursing students	Qualitative	Interviews	N/A

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Curtis, K et al.	2012	UK	Uniprofessional	19	Nursing students; nb data from health service staff and patients, and educators, used to contextualise findings	Qualitative	Interviews	N/A
DeForge, BR & Sobal, J	1989	USA	Uniprofessional	609	First-year medical students	Quantitative	Questionnaire (Budner's Intolerance of Ambiguity Scale)	N/A
Dodgson, JE et al.	2018	Japan / USA	Multiprofessional	13	Nursing students	Qualitative	Interviews	N/A
Drummond, I et al.	2016	UK	Uniprofessional	28	Final-year medical students	Qualitative	Focus groups	Tactical decision games
Duvivier, R et al.	2014	Netherlands	Uniprofessional	32	Fourth-year medical students	Qualitative	Focus groups	Clinical clerkships
Eley, DS et al.	2017	Australia	Uniprofessional	797	Medical students	Quantitative	Questionnaire (The Multiple Stimulus Types Ambiguity Tolerance Scale-II; The Resilience Scale; Frost Multidimensional Perfectionism Scale)	Clinical rural immersion programs
Evans, L et al.	2012	USA	Uniprofessional	89	Medical students	Quantitative	Questionnaire (Physicians' Belief Scale; Physicians' Reactions to Uncertainty Scale)	Early clinical experience course and continuity clinical experience course
Fagundes, ED et al.	2020	Brazil	Uniprofessional	60	Medical students	Quantitative	Observation data (audio-recorded case presentations)	SNAPPS; One-minute preceptor; Case presentations; Clinical clerkships
Fernandez, N et al.	2016	Canada	Uniprofessional	404	Medical students	Qualitative	Questionnaire (open questions)	Learning-by-Concordance approach

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Finnerty, G & Pope, R	2005	UK	Uniprofessional	3	Midwifery students	Qualitative	Observation data (audio-diaries)	Non-formal learning in the clinical setting
Framback, JM et al.	2012	Netherlands	Uniprofessional	nc	Medical students; Educators	Qualitative	Interviews; Observation data (PBL tutorials)	Problem-based learning
Friary, P et al.	2018	New Zealand	Multiprofessional	22	Physiotherapy students; Other students; Patients; Educators	Qualitative	Interviews; Focus groups	Interprofessional education
Ganesh, A & Ganesh G	2010	India	Uniprofessional	16	Final-year medical students	Qualitative	Observation data (written diaries)	Clinical setting
Gärtner, J et al.	2020	Germany	Uniprofessional	67	Medical students	Qualitative	Observation data (video-recorded case presentations)	Simulation-based learning
Gaufberg, E et al.	2018	USA	Uniprofessional	585	Medical students	Quantitative	Questionnaire (Jefferson Scale of Empathy; Patient-Practitioner Orientation Scale; Budner's Tolerance of Ambiguity Scale; Ways of Coping Questionnaire–22 Item; Medical School Learning Environment Survey	Humanities activities
Geller, G et al.	1990	USA	Uniprofessional	386	Medical students	Quantitative	Questionnaire (modified version of Budner's Intolerance of Ambiguity)	N/A
Gibson, KR et al.	2014	UK	Uniprofessional	183	Final-year medical students; Educators	Quantitative	Questionnaire (student and tutor versions); Attendance; Examination performance	A junior doctor-led prescribing tutorial programme
Gonzalo, JD et al.	2020	USA	Uniprofessional	710	Medical students	Qualitative	Questionnaire (open questions)	Health systems science
Gormley, GJ & Fenwick, T	2016	UK	Uniprofessional	8	Fourth-year medical students	Qualitative	Interviews; Observation data (video footage)	Ward-based simulation teaching activity

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Gowda, D et al.	2018	USA	Multiprofessional	35, 44, 18	First-year medical students	Mixed methods	Questionnaire open and closed questions (Groningen Reflection Ability Scale, modified version of Budner's Tolerance for Ambiguity scale, Best Intentions Questionnaire); Focus groups; Written narrative evaluations	Museum-based art course
Groot, F et al.	2020	Netherlands	Uniprofessional	11	Medical students	Qualitative	Interviews	Simulation-based learning
Han, PKJ et al.	2014	USA	Uniprofessional	28	Second-year medical students	Quantitative	Questionnaire (closed questions); Observation data (SP Risk Communication Process, Risk Communication Content)	Risk communication curriculum
Han, PKJ et al.	2015	USA	Uniprofessional	58	Medical students	Quantitative	Questionnaire (Tolerance for Ambiguity, Pearson Risk Attitude, Ambiguity Aversion in Medicine)	N/A
Hancock, J et al.	2017	UK	Multiprofessional	525	Medical students; Veterinary students	Quantitative	Questionnaire (Tolerance of Ambiguity of Medical Students and Doctors Scale, Tolerance of Ambiguity of Veterinary Students Scale)	N/A
Handwerker, SM	2018	USA	Uniprofessional	11	Nursing students	Qualitative	Interviews	N/A
Hayward, J et al.	2016	Canada	Uniprofessional	301	Second-year medical students	Qualitative	Observation data (narrative response of student feedback on patient cases)	Virtual patients; Simulation; Case-based learning
Hazel, SJ et al.	2013	Australia	Uniprofessional	264	First-year veterinary students; Other students	Mixed methods	Questionnaire open and closed questions; Student group marks	Team-based learning
He, B et al.	2019	USA	Uniprofessional	65	Medical students	Qualitative	Questionnaire (open questions)	Arts-based learning
Helmich, E et al.	2018	Netherlands/ Canada	Uniprofessional	29	Medical students; Doctors	Qualitative	Interviews	N/A
Huijer, M et al.	2000	Netherlands	Uniprofessional	nc	Medical students	Quantitative	Case reports	Clinical setting

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Ion, R et al.	2015	UK	Uniprofessional	13	Final-year (adult and mental health) nursing students	Qualitative	Interviews	N/A
Ironside, PM	2003	USA	Uniprofessional	33	Nursing students; Educators	Qualitative	Interviews	N/A
Ironside, PM et al.	2009	USA	Uniprofessional	413, 67	Final-year nursing students	Quantitative	Questionnaire (Multiple Stimulus Types Ambiguity Tolerance Scale-I, investigator-developed patient safety instrument)	Multiple-patient simulation experiences
Johnsen, H	2016	Denmark	Multiprofessional	71	Midwifery students; Physiotherapist students; Other students	Qualitative	Questionnaire, “open ended questions”; Focus groups	Technology enhanced learning: student projects.
Jowsey, T et al.	2020	New Zealand	Multiprofessional	115	Medical students; Pharmacy students, Nursing students; Other students	Qualitative	Observation data (participant observation, field notes, interviews, photography and observational ethnographic film)	Inter-professional learning; Simulation-based learning; Reflection
Kashbour, WA et al.	2019	UK	Uniprofessional	28	Dentistry students	Qualitative	Focus groups	Clinical setting; Early clinical training
Klugman, CM et al.	2011	USA	Multiprofessional	32	Medical students; Nursing students	Mixed methods	Questionnaire (Budner’s Tolerance of Ambiguity Scale, The Communication Skills Attitudes Scale); Texts (free responses to art and patient images)	Art rounds program/ visual thinking strategies
Koufidis, C et al.	2020	Sweden	Uniprofessional	23	Medical students	Qualitative	Interviews; Observation data (participant observations, field interviews)	Clinical teaching
Kristiansson, MH et al.	2014	Sweden	Uniprofessional	35	Medical students	Qualitative	Observation data (written reflections)	Reflective writing
Krupat, E et al.	2011	USA	Uniprofessional	35	Third-year medical students	Mixed methods	Observation data (written reflections)	Clerkship/ Clinical year placements

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Landeen, J et al.	2013	Canada	Uniprofessional	31	Nursing students; Educators	Qualitative	Interviews; Focus groups	Problem-based learning
Leh, SK	2011	USA	Uniprofessional	42	Nursing students	Qualitative	Focus groups	Clinical rotations
Lemmon, ME et al.	2018	USA	Uniprofessional	159	Medical students	Mixed methods	Questionnaire (open and closed questions); Observation data (electronic communication tracker); Focus groups	Clinical clerkships
Lewinson, L et al.	2018	UK	Uniprofessional	13	Final-year students	Qualitative	Interviews	N/A
Lingard, L et al.	2003	Canada	Uniprofessional	21	Medical students	Qualitative	Interviews; Observation data (case presentations and related teaching exchanges)	Case presentations; Clinical clerkships
Lingard, L et al.	2003	Canada	Uniprofessional	26	Medical students	Qualitative	Interviews; Observation data (case presentations and related teaching exchanges)	Case presentations; Clinical clerkships
Liou, KT et al.	2019	USA	Uniprofessional	23	Medical students	Quantitative	Budner's Tolerance of Ambiguity scale	Equine-facilitated learning
Llapa Rodrigues, EO et al.	2016	Brazil	Uniprofessional	116	Nursing students	Quantitative	Questionnaire (KEZKAK Questionnaire, validated for the Portuguese language	N/A
Lodewyk, K et al.	2020	Canada	Uniprofessional	61	Medical students	Quantitative	Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD); Questionnaire (investigator-developed sports background instrument)	N/A
Mangione, S et al.	2018	USA	Uniprofessional	739	Medical students	Quantitative	Questionnaire (investigator-developed humanities exposure instrument; Brief Wisdom Screening Scale; Jefferson Scale of Empathy; Budner's Tolerance for Ambiguity Scale; Wong and Law's Emotional Intelligence Scale; 10-item generalized self-efficacy scale; Santa Barbara Solids Test	Humanities activities

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Markey, K et al.	2018	Ireland	Uniprofessional	30	Nursing students; Nurses	Qualitative	Interviews; Focus groups	N/A
Markey, K et al.	2019	Ireland	Uniprofessional	71, 30	Nursing students; Nurses	Qualitative	Interviews; Focus groups	Clinical setting
Matchim, Y & Raetong, P	2018	Thailand	Uniprofessional	21	Nursing students	Qualitative	Interviews	Clinical setting
Maudsley, G et al.	2008	UK	Uniprofessional	695	Medical students	Mixed methods	Questionnaire (open questions resulting in textual and numerical data)	Problem-based learning
McCarthy, J et al.	2018	Ireland	Multiprofessional	12	Nursing students (Intellectual disability, mental health); Midwifery students	Qualitative	Interviews	Clinical placements
Merrill, JM et al.	1994	USA	Uniprofessional	1009	Medical students	Quantitative	Questionnaire (investigator-developed intolerance of ambiguity instrument, incorporating Budner's Tolerance for Ambiguity Scale)	N/A
Mol, SS et al.	2019	Netherlands	Uniprofessional	35	Medical students; Doctors	Mixed methods	Questionnaire; Focus groups; Observation data (logbooks)	Clinical setting
Morton, KR et al.	2000	USA	Uniprofessional	130	Medical students	Quantitative	Questionnaire (Budner's Intolerance of Ambiguity, The Interpersonal Reactivity Index); Examination performance (standardized patient ratings)	N/A
Nevalainen, MK et al.	2010	Finland	Uniprofessional	22	Medical students	Qualitative	Observation data (reflective learning diaries)	Reflective thinking course; Clinical setting
Nevalainen, MK et al.	2012	Finland	Uniprofessional	307	Fifth-year medical students	Quantitative	Questionnaire (investigator-developed intolerance of uncertainty instrument)	Clinical setting

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Neve, H et al.	2017	UK	Uniprofessional	22	Medical students; Educators	Qualitative	Observation data (audio-diaries, discussion groups)	Small groups ('Jigsaw' groups)
Nguyen, M et al.	2016	Canada	Uniprofessional	58	Medical students; Educators	Quantitative	Questionnaire (investigator-developed instrument with versions for students and educators, open and closed questions)	Arts-based learning activities
Nixon, J et al.	2014	USA	Uniprofessional	191	Medical students	Quantitative	Observation data (educational prescriptions)	SNAPPS-Plus i.e. includes a PICO-formatted educational prescription; Case presentations; Clinical clerkships
Porteous, DJ & Machin, A	2018	UK	Uniprofessional	10	First-year nursing students (child, mental health, learning disability, adult)	Qualitative	Interviews; Observation data (audio-diaries)	N/A
Ramos-Morcillo, AJ et al.	2020	Spain	Uniprofessional	32	Nursing students	Qualitative	Interviews	N/A
Riegelman, RK et al.	1983	USA	Uniprofessional	198	Medical students	Quantitative	Questionnaire (Investigator-developed literature-reading instrument)	Reading medical literature
Rowan, CJ et al.	2008	UK	Uniprofessional	96	Midwifery students	Qualitative	Focus groups	Problem-based learning
Sawanyawisuth, K et al.	2015	Thailand	Uniprofessional	32	Fifth-year medical students	Quantitative	Observation data (audio-recorded case presentations)	SNAPPS; Case presentations; Clinical clerkships
Schéle, I et al.	2011	Sweden	Uniprofessional	15	Dentistry students; Educators	Qualitative	Interviews	N/A
Scott, A et al.	2020	UK	Uniprofessional	45	Medical students	Qualitative	Observation data (de-briefing transcripts)	Simulation-based learning

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Senette, L et al.	2013	USA	Multiprofessional	26	Nursing students; Other students	Mixed methods	Questionnaire (incorporating Attitude Toward Collaborative Learning Scale, open and closed questions)	Simulation activity
Sobal, J & DeForge, BR	1991	USA	Uniprofessional	171	Medical students	Quantitative	Questionnaire (investigator-developed tolerance of uncertainty instrument, incorporating Budner's Tolerance for Ambiguity Scale)	N/A
Stephens, GC et al.	2020	Australia	Uniprofessional	207, 24	Medical students	Qualitative	Interviews; Observation data (online discussion forum text)	Online discussion of anatomy topics
Steinauer, JE et al.	2018	USA	Uniprofessional	26	Fourth-year medical students	Qualitative	Interviews	Clinical setting
Stone, JP et al.	2015	Canada	Uniprofessional	72	Final-year medical students; Graduated doctors	Mixed methods	Questionnaire (investigator-developed with open and closed questions)	Clinical setting
Toivonen, AK et al.	2017	Finland	Uniprofessional	351	Fourth-year medical students	Qualitative	Observation data (written reflections)	Communication skills course
Vae, KJU et al.	2018	Norway	Uniprofessional	33	Nursing students; Educators	Qualitative	Interviews	Clinical setting

Table 2: Continued.

Authors	Year	Country	Discipline	Study population (n)	Study population	Research design	Methods	Relevant teaching/ learning strategies
Van Ryn, M et al.	2014	USA	Uniprofessional	4732	First-year medical students	Quantitative	Questionnaire (incorporating Jefferson Empathy Scale Student Version, The Medical Authoritarianism Scale, and portions of Interpersonal Reactivity Index, Need for Closure Scale, Social Dominance Orientation Scale, Pearlin's Mastery Scale, Rosenberg Self Esteem Scale, Patient-Reported Outcome Measurement Information System Short Forms Scales	N/A
Warner, TD et al.	2001	USA	Uniprofessional	166	Medical students	Quantitative	Questionnaire (instrument developed by the Therapeutic Care Committee of the Group for the Advancement of Psychiatry)	N/A
Watkins, KD et al.	2011	South Africa	Uniprofessional	44	Nursing students	Qualitative	Interviews; Focus Groups; Observation data (written diaries)	N/A
Wayne, S et al.	2011	USA	Uniprofessional	313	Medical students	Quantitative	Questionnaire (Medical Students' Attitudes Toward the Underserved, Budner's Intolerance of Ambiguity Scale)	N/A
Weurlander, M et al.	2019	Sweden	Uniprofessional	14	Medical students	Qualitative	Focus groups	N/A
Wolpaw, T et al.	2009	USA	Uniprofessional	64	Medical students	Quantitative	Observation data (audio-recorded case presentations)	SNAPPS; Case presentations; Clinical clerkships
Wolpaw, T et al.	2012	USA	Uniprofessional	60	Medical students	Qualitative	Secondary analysis of audio-recorded case presentations	SNAPPS; Case presentations; Clinical clerkships
Young-Brice, A et al.	2018	USA	Uniprofessional	20	Nursing students	Qualitative	Interviews	N/A

N/A – not applicable; nc – not clear

Factors that influence learner experiences

Individual factors

A large proportion of the literature examined individual learner differences with some evidence that gender, age, background, discipline, and stage of training could impact on how learners interact with uncertainty[53,57,60,78,93,99-103]. However, the heterogeneity of study designs made it difficult to draw general conclusions. For example, whilst some studies suggested that male students managed uncertainty better than female[80], others suggested that females fared better[5,99,100] a further three papers found no gender differences[63,104,105]. Several researchers commented on the multi-dimensional nature of uncertainty, and how different assessment instruments can lead to different outcomes[5,101,106,107].

System factors

Other studies identified a range of non-individual, or system, factors which influenced learners' experiences of uncertainty. Studies identified both local (i.e., specific clinic setting, organisational culture)[67,68,82,87,108] and wider (i.e., professional socialisation, socio-cultural issues)[51,68,71,85,109-111] contextual factors that impacted on how learners experience uncertainty. Several papers described a health professions' culture which, paradoxically, places value on certainty over uncertainty[65,112,113].

Educational outcomes

Negative narrative

Overall, the narrative around learners' experience of uncertainty tended to be articulated in negative terms. Researchers described these experiences using words such as "discomfort", "stress", "anxiety", and "vulnerability"[56,57,66,68,70-73,76,79,83,97,94-96,114,115,119,123]. This was particularly evident for studies which described nursing students' experiences in the clinical setting[56,70-72,79,83,87,135].

Learner approaches to uncertainty

Several papers indicated that an ability to manage uncertainty represented an important component of learners' professional identity[57,97,116,117]. Learners themselves displayed a wide range of approaches to uncertainty[56-58,67,87,97,114,118]. Strategies described in the literature included: learners letting go of perfectionism, adapting ideals to fit reality, being honest when lacking knowledge, asking for help, and understanding what it means to be "good enough"[54,66,80,85,97].

Learners tended to avoid or deny uncertainty, especially in assessment situations. Whilst some learners attempted to "self-preserve", by avoiding expressions of uncertainty[65,112] and avoiding asking questions[81,87], others appeared to place blame onto patients[119]. This position was countered by one qualitative study, which found scant evidence of a denial of uncertainty in their medical student cohort[97]. Several papers highlighted the importance of

socio-cultural background, e.g. country of origin, on learners' likelihood to respond openly to uncertainty[109-111].

Many researchers described a maturation process, i.e., that learners' responses to uncertainty evolve as they accumulate experience and academic maturity[5,57,63,80,93,97,107,112,113,117,118,120]. Only one study indicated that uncertainty tolerance did not change as learners progressed through their training, a finding which may relate to the study's cross-sectional design[100].

Impact on learning

Several papers discussed the links between students' capacity to manage uncertainty and their academic performance[121-123], career preferences[5,80,100,102], ability to empathise[87,116,122,124], and attitudes towards patients[5,100,112,119,125] with mixed and occasionally conflicting findings. Several papers proposed that uncertainty presents a barrier to learning, i.e., causing students to become less self-directed, proactive, and effortful in their learning[51,110,110,126]. Other researchers commented that uncertainty under certain circumstances could be "productive", i.e., where appropriate supports are in place, this can act as a catalyst for learning[52,58,71].

Teaching and learning approaches

Several studies focused on existing approaches to teaching and learning around uncertainty from the perspectives of content ("what") and process ("how"). With regards to the former, learners met uncertainty when engaging with topics such as professionalism, communication, ethics, clinical reasoning, evidence-based medicine, and inter-professional learning[32,60,107,127-130,150]. With regards to the latter, a number of formal teaching strategies which intended to help learners to work with uncertainty, were described. These studies largely fell into two groups: arts-based teaching which addressed issues of uncertainty and ambiguity[105,131-133], and clinical teaching which used SNAPPS, a clinical reasoning scaffold with a specific focus on identifying uncertainties[62,109,134-136]. Other studies suggested that learners could develop ways to manage uncertainty through use of the Learning-by-Concordance approach[137], simulation[138] and a novel equine-facilitated workshop which introduced horses to medical students as "experiential surrogates for ambiguity" [139(p.960)].

Learners also had opportunities to develop their capacity to manage uncertainty in other, more indirect ways, e.g. through problem-based learning[55,74,93,140] and simulation[60,108,123,141-143]. With regards to the former, researchers recommended that sessions should be actively tutored, and cases not overtly scripted, to support learning around uncertainty[69,74,93]. Teaching in the clinical setting was also important, with an emphasis on building supportive educator-learner relationships[51,56,112,144].

Other educational strategies that emerged included team-based learning[32], small group learning[128,145], tactical games[146], virtual patients[147], online discussion of anatomy topics[118], and

non-specified humanistic activities[116,148]. Reflective practice was also mentioned within the literature and researchers described a variety of techniques which could be usefully applied, including: discussions with mentors[51,58], small group exercises[61,117], written reflection[59,66,97], and combinations of these[58,76,80,128,131,149].

Specific teaching approaches to support learning around uncertainty were mentioned within the studies. These included: helping learners to reach a sense of "good enough"[97]; encouraging learners to keep questioning what they think they know[61]; directly acknowledging that ambiguity and uncertainty exist within health professions' work[68,125]; helping learners to understand that success has different meanings; teaching thinking in ways that preserve uncertainty and fallibility[121]; managing expectations around controlling uncertainty[114]; leveraging learners' experiences of uncertainty in non-academic settings such as sports participation[103], and providing extra support to ethnic minority students[78]. Table 3 shows a summary of our major findings.

Table 3: Summary of main findings

Theme	Sub-theme	Description	Studies
Learners' interactions with uncertainty	Types of learners	A wide variety of health professions' learners meet uncertainty within the context of their undergraduate studies. Most studies reported on cohorts of medical and nursing students, with mentions also of physiotherapy, midwifery, veterinary, dentistry and pharmacy students. All stages of undergraduate training are represented.	32, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60
	Types of uncertainty	Types of uncertainty can be categorised into: (i) uncertainty related to practice of healthcare itself; (ii) uncertainty related to the educational process; and (iii) uncertainty related to the self. The types of uncertainty that learners experienced, and their concerns around these, evolved as they progressed through their education.	32, 54, 55, 56, 57, 58, 59, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98
Factors that influence learner experiences	Individual factors	There was some evidence that factors such as sex, age, background, discipline, and stage of training could impact on learner experiences of uncertainty, but the heterogeneity of study designs made it difficult to draw general conclusions.	5, 53, 60, 63, 78, 80, 93, 99, 100, 101, 102, 103, 104, 105, 106, 107
	System factors	Studies described a range of local and wider contextual factors which impacted on how learners experience uncertainty.	51, 64, 65, 67, 68, 71, 82, 85, 87, 108, 109, 110, 111, 112, 113
Educational outcomes	Negative narrative	Overall, the narrative around learners' experience of uncertainty tended to be negative. This was particularly evident for studies which described nursing students' experiences in the clinical setting.	56, 57, 66, 68, 70, 71, 72, 73, 76, 79, 83, 87, 94, 95, 96, 114, 115, 119, 123
	Learner approaches to uncertainty	Several papers indicated that an ability to manage uncertainty represented an important component of learners' professional identity. Learners displayed a wide range of approaches to uncertainty. Some studies commented on learners avoiding or denying uncertainty, especially in situations where they were being assessed. Many researchers indicated that learners undergo a maturation process in respect to uncertainty.	5, 54, 56, 58, 65, 66, 67, 80, 81, 87, 93, 97, 100, 103, 107, 109, 110, 111, 112, 114, 116, 118, 119, 120

Table 3: Continued.

Theme	Sub-theme	Description	Studies
	Impact on learning	Studies examined correlations between students' capacity to manage uncertainty in relation to their academic performance, career preferences, ability to empathise, and attitudes towards patients. Several papers proposed that uncertainty presents a barrier to learning, whilst others considered that it could be productive.	51, 52, 58, 65, 71, 80, 87, 102, 110, 111, 116, 119, 121, 122, 123, 124, 125, 126
Teaching and learning approaches		Several papers discussed specific "homes" within health professions' curricula for supporting learning around uncertainty. Uncertainty was highlighted as a component of topics such as professionalism, communication, ethics, clinical reasoning, evidence-based medicine, and interprofessional learning. Direct teaching strategies included arts-based teaching, clinical case presentations using the SNAPPS model, Learning-by-Concordance, simulation and equine-facilitated learning. Other teaching strategies included: problem-based learning, clinical teaching, humanities teaching, simulation, team-based learning, small group learning, tactical games, online discussion of anatomy topics, and virtual patients. Reflection and reflective practice were also mentioned within the literature.	32, 51, 55, 56, 58, 59, 61, 62, 65, 66, 68, 69, 74, 76, 78, 80, 93, 97, 103, 107, 109, 114, 116, 117, 118, 121, 123, 60, 125, 127, 128, 129, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 143, 144, 145, 146, 147, 148, 149, 150

DISCUSSION

In seeking to explore how undergraduate health professions' students learn to engage with uncertainty in their professional practice, this review highlights that the experience of uncertainty is ubiquitous within health professions' education. It is clear that a wide variety of learners, from different professions and countries, engage with uncertainty at all stages of their training.

The review sheds light on the nuances of uncertainty for health professions' learners. Different types exist; from the uncertainty related to interactions with the healthcare and educational processes, to the uncertainty students experience in relation to their own selves. These types of uncertainty arise for learners in many varied teaching and learning settings (although uncertainty related to lecture-based teaching was conspicuous in its absence). Problem-based learning seems to provide an important crucible for engaging with uncertainty, as does workplace-based learning. Our review also reinforces the idea that transitions, e.g., entering clinical rotations, provoke experiences of uncertainty for health professions' learners[91,92].

In keeping with the wider literature, this review highlights the various ways in which learners navigate uncertainty, and that both individual and context-related factors influence this process. It seems that learners also build a capacity to manage uncertainty as they progress through their training. Several studies refer to this phenomenon as a "maturation process",

and it's unclear to what extent this unfolds due to students' accumulation of learning and experience, or to socialisation within their chosen profession. Our findings lack detail around what, specifically, this maturation looks like. Existing longitudinal studies tend to track learners' engagement with uncertainty through the lens of a psychological construct, i.e. tolerance of uncertainty[43]. However, cross-sectional qualitative studies suggest that the learners mobilise a wide range of knowledge, skills and attitudes in relation to uncertainty, a level of granular detail that may not be captured fully by existing research designs.

Whilst our review suggests that students meet with uncertainty many times during their training, there were few examples of direct teaching, i.e., through arts-based approaches[105,131-133] or clinical cases[62,109,134-137]. When compared to other non-technical domains such as communication and team skills, this apparent scarcity is surprising[151,152]. This finding might be explained by how uncertainty and its management is conceptualised. Until recently, tolerance of uncertainty has largely been framed as a stable personality trait, although it is now considered at least partly amenable to training[4]. The idea that the capacity to manage uncertainty is personality-driven, and is mostly taught indirectly rather than directly within health professions' education, recalls the early days of the communication skills movement. Thirty years ago we asked ourselves "can communication skills be taught?"[153]; could uncertainty management occupy a similar trajectory?

There may also be a reluctance to provide training around uncertainty due to its perception as a difficult, uncomfortable topic for healthcare professionals. Our review highlights a negative narrative around managing uncertainty, with learners' frequently discussing it in terms of stress or strain. These descriptions link back to the wider literature which connects uncertainty with feelings of discomfort and anxiety[154-158]. In our review, this negativity was most apparent within cohorts of clinical nursing students. It is not clear whether there are particular characteristics to this context which are specifically negative, or if, perhaps, nursing students' are more inclined to express and discuss the emotional aspects of their practice?

What this review does outline is that students' experiences of uncertainty have several effects. In some cases, uncertainty acts as a barrier to learning[51,110,111,126,138]. In others, it elicits behaviour change e.g. learners attempt to "self-preserve", by avoiding expressions of uncertainty[65,112] or even placing blame onto patients[119]. This supports the idea that health professions' learners feel pressure to preserve the semblance of competence in front of their teachers, engaging in impression management[159-161].

The included studies say less on the benefits of engaging with uncertainty. One study[52] proposes that "some uncertainty or stress is needed to shift learning to a new level." This is supported in the educational literature, where there is a growing recognition that experiences of uncertainty are important catalysts for deeper learning[162,163]. However, the

authors highlight that uncertainty is only "productive" under certain circumstance i.e., when it does not undermine trust and confidence. It implies then that some experiences of uncertainty may be more helpful than others to students. This idea has been discussed previously with the idea that "good uncertainty... provides students opportunities to engage with the unknowns of a challenge in an otherwise supportive, well-structured environment", whilst "bad" uncertainty results in chaos[164]. In a health professions' context we might hypothesise that a student who interacts with a patient from a different socio-cultural background, experiences a "productive" uncertainty, whilst one who can't find their classroom experiences one that is "unproductive". There appears to be little objective data, and a gap in the literature, in relation to how these experiences are perceived and managed by students, and what outcomes result.

Despite the further issues that this review provokes around how learners engage with uncertainty, we do know that there are many opportunities for health professions' educators to support them on this journey. Topics that commonly appear on health professions' curricula, e.g. professionalism, communication, ethics, clinical reasoning, can provide a "home" for learning around uncertainty. Similarly, teaching settings such as problem-based learning contexts, and the clinical workplace lend themselves to experiential learning around this domain. Finally, educators can help their learners to manage and make sense of uncertain situations through supportive mentoring and role modelling, and through involving them in well-structured reflective exercises[165].

FUTURE RESEARCH

With regards to future research, an increased focus on longitudinal studies which employ qualitative or mixed method approaches could provide more detailed information on how students build their capacity to manage uncertainty during their training. Further work is also required to explore how learners' experiences with specific types of uncertainty impact on learning processes, i.e., can we recognise and foster more "productive" experiences of uncertainty for students? Finally, expanding the scoping review approach to cover postgraduate training and cross-cultural studies, would improve our understanding of this issue.

STRENGTHS AND LIMITATIONS

We used a broad search strategy in order to maximize inclusivity and generate an overview of uncertainty in the literature. Thus, we kept the initial search open to all levels of health professions' training, an approach which yielded a high volume of papers. To limit the papers to a feasible data set, we chose to focus only on "uncertainty" and "ambiguity" (although we had tested other synonyms). Similarly, we restricted our searches to papers published during or after 1950, and to those published in the English language. Given the potential breadth of the field, future reviews may consider using variations of the search strategy

we have documented, and might include utilising forward citation methods to improve the sensitivity and specificity of the literature search results.

CONCLUSIONS

Training for uncertainty has been described as medical education's "most elusive ideal"[28]. This scoping review allows us to track down this concern, providing an overview of how health professions' students learn to engage with uncertainty during their undergraduate training. We have found that uncertainty is a ubiquitous concern in health professions' education, with students experiencing different forms of uncertainty at many stages of their training. These experiences are influenced by both individual and system-related factors.

Whilst formal teaching to support learning around uncertainty is infrequent, specific strategies do exist, i.e., arts-based teaching, and clinical case presentations. Other types of teaching provide ways for students to meet with uncertainty indirectly, including problem-based learning, clinical teaching, humanities teaching, simulation, team-based learning, small group learning, tactical games, and virtual patients. Reflection and reflective practice are also mentioned as strategies to address learner experiences of uncertainty within the literature.

CONTRIBUTORS

JM, JH and TP conceptualised the study. JM, JH, TP and PM contributed to the study design. JM and JH led the data collection and analysis with support from TP. JM produced the first draft of the paper; all four authors (JM, JH, TP and PM) contributed to and refined this draft. All four authors approved the final manuscript for submission.

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to Drs Erica Smith, Muirne Spooner and Aisling Kerr for their generous peer support during the scoping review process.

FUNDING

Internal funding from RCSI HPEC (Health Professions Education Centre) was provided for this paper.

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“It’s okay to not know…” a qualitative exploration of faculty approaches to working with uncertainty

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Published in: BMC Medical Education, 22(1): 135.

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ABSTRACT

Whilst it is recognised that a capacity to manage uncertainty is an essential aspect of working as a healthcare professional, there is little clear guidance on how to facilitate student learning in this domain. A lack of faculty development opportunities also suggests that health professions' educators may feel ill-equipped to assist students in developing effective approaches to uncertainty. The purpose of this study was to explore a faculty development intervention designed to help educators unpack students' experiences of uncertainty, and identify attributes that may help students to manage uncertain situations.

This qualitative study was informed by a constructivist methodological approach, where participants were encouraged to share meaning around the nature of uncertainty in health professions' education. Two 90-minute faculty development sessions were held. These sessions invited participants to apply Han *et al.*'s taxonomy of uncertainty to role-played scenarios of student uncertainty within a focus group setting. Focus group data were collected, and examined using a two-stage, hybrid approach of deductive and inductive thematic analysis.

Han *et al.*'s taxonomy helped participants to identify multiple sources and issues of uncertainty in the role played scenarios, thus unveiling the extent of uncertainties encountered by health professions' learners. Data analysis revealed four themes overall: "Sources of uncertainty", "Issues of uncertainty", "Uncertainty attributes", and "Learning environment." Participants also contributed to a list of attributes that they considered helpful to undergraduate health professions' students in managing uncertain situations. These included an awareness of the nature of uncertainty within healthcare practice, an ability to recognise uncertainty, and adopting attitudes of adaptability, positivity, and resilience.

This study highlights the successful use of Han *et al.*'s taxonomy of uncertainty within a faculty development setting. Our findings suggest that the taxonomy is a practical and versatile tool that health professions' educators can use in shared reflections and conversations around uncertainty with students or colleagues.

BACKGROUND

Health professionals encounter uncertainty on a daily basis, as they attempt to make sense of complex situations and make decisions despite limited or unclear information. A capacity to manage uncertainty is essential for the wellbeing of health professionals[1,2] and the patients in their care[3]. There have been persistent calls to address uncertainty within health professions' curricula[4-7], thus preparing our graduates of the future for a "supercomplex" world[8].

However, whilst a capacity to manage uncertainty has been recognised as a core dimension of professional competence[9], and is now a regular addition to professional competency-based frameworks[10-13], there is no consensus on how to support effective learning around uncertainty. A recent scoping review reveals that although health professions' students meet uncertainty regularly within the context of their undergraduate training, they appear to receive little, if any, formal training on how to manage this[14].

Uncertainty can be understood as a "subjective perception of not knowing what to think or what to do"[15(p.3)].This is a frequent experience for health professionals which can influence clinical decision-making and professional practice. Yet, there are few published examples of teaching interventions that specifically address uncertainty management. One explanation may be the lack of clear evidence which links training around uncertainty to explicit, measurable and positive outcomes. White and Williams[16(p.1202)] state that although there is a "substantial body of evidence in support of the implementation of formal teaching regarding uncertainty… There have been no trials on which to base judgements about the long–term effectiveness, outputs, value for money and beneficial effects on practitioner resilience and performance [of this teaching]."

This situation may be about to change. Although research into uncertainty in health professions' education has existed for more than half a century[17], more recent work has built a compelling case for using educational interventions to influence learners' uncertainty management[18-20]. Stephens *et al*.[21(p.72)] state that "education may be a formidable moderator of tolerance of uncertainty, with multiple aspects of the learning environment impacting student tolerance of uncertainty. Therefore, educators should feel confident in trying to incorporate tolerance of uncertainty paradigms into existing curricula, even traditionally content-heavy science courses." Returning to our opening question around teaching interventions, perhaps the word "should" holds a clue? Although educators *should* feel confident to offer teaching around uncertainty, it is distinctly possible that they do not.

A recent increase in research around uncertainty in health professions' education has also revealed subtle but important shifts in thinking[14]. Whilst older studies have focused on how to raise learners' tolerance for ambiguity, newer work hints at a more nuanced balance

between tolerance and intolerance[22]. In other words, educators face ambiguity in planning how to help their students to face ambiguity. Further to this, educators may also view uncertainty, overall, with some trepidation. As Hillen *et al.*[23(p.63)] explain: "Uncertainty can be aversive; large bodies of research from multiple disciplines, both in and outside of the health care domain, have demonstrated that uncertainty provokes fear, worry and anxiety, perceptions of vulnerability, and avoidance of decision-making." These factors combine to explain why educators may not feel confident to offer teaching around uncertainty or, indeed, to disclose the full extent or nature of their own uncertainties.

Despite these many potential reasons for health professions' educators' reluctance to engage with uncertainty, it seems clear that they act as an influential presence in helping learners to cope with uncertain situations, e.g. through role modelling and mentoring[14,24]. It is likely, then, that educators may need assistance to reach their potential here, making the ways that they themselves respond to uncertainty explicit and tangible as they guide students. As Domen[25(p.4)] states, "a greater emphasis should be placed on the teaching of ambiguity to residents and faculty who, ultimately, have the greatest influence on the qualities and behaviours we hope to instil in our students, residents, and other learners." There is, however, a surprising lack of research into faculty development around strategies for uncertainty[26,27], and little guidance on how to equip faculty to recognise and engage with students' experiences of uncertainty. It is reasonable to consider that effective faculty development interventions may empower health professions' educators to notice and harness opportunities to support learning, both formal and informal, around uncertainty.

The purpose of this study is to explore a faculty development intervention designed to help educators unpack simulated experiences of student uncertainty. Using role-played vignettes derived from real-life experiences to trigger discussions around uncertainty, we aimed to deepen educators' understanding of where uncertainty manifests within health professions' education, and how students can be helped to manage its accompanying challenges. With regards to the latter, we wanted to gather educators' perspectives on the student attributes (knowledge, skills and attitudes) that would represent foundational competence in managing uncertainty[28]. By specifically defining the attributes that make up the construct of uncertainty management and tolerance, we hoped this would make both implicit and tacit learning around uncertainty more explicit, as well as providing educators with a framework for supporting students when they reflect on uncertain situations.

Our faculty development intervention employed Han and colleagues'[29] taxonomy of uncertainty as a conceptual framework. This taxonomy organises experiences of uncertainty according to three dimensions: source, issues and locus (Figure 1). The *locus* of the uncertainty is the person to which the uncertainty relates. The *sources* of uncertainty are where the uncertainties arise from. These can be categorised as probability (the indeterminacy of a

future event occurring), ambiguity (the lack of adequate, reliable or credible information) or complexity (aspects of the situation that make it difficult to understand). The *issues* of uncertainty are the substantive issues about which an individual is uncertain. These can be categorised as scientific or data-centred (uncertainty related to a medical condition), practical (uncertainty related to the system, structures, or processes) or personal (uncertainty related to the individual). We chose this taxonomy as it has been demonstrated as a practical way to facilitate "an organized approach to the problem of uncertainty"[29(p.1)] in a wide range of healthcare contexts[30-36]. Using this taxonomy also allowed us to situate our study within the wider body of literature on uncertainty in healthcare, helping to contribute to "a more systematic program of research based upon shared, integrative conceptual models"[37(p.1756)].

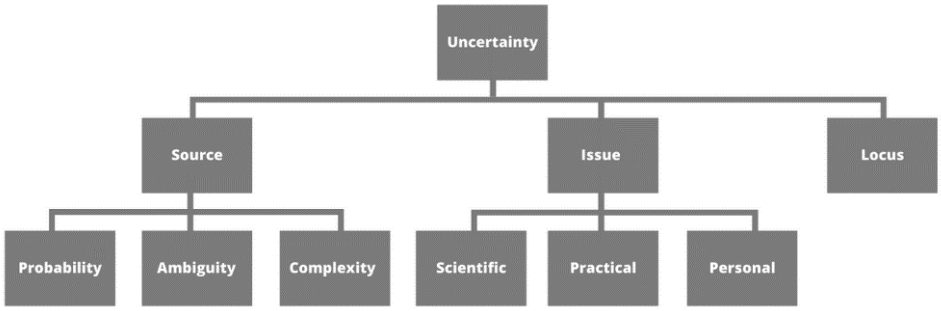

Figure 1: Han and colleagues' (2011) taxonomy organises uncertainty according to three dimensions: source, issue and locus

Here, we used the taxonomy to help faculty participants to "distinguish and understand… specific uncertainties"[33(p.918)], and reflect on how uncertainty arises and unfolds in health professions' education. Through applying the taxonomy to role-played scenarios, we reasoned that participants would gain deeper insight into what attributes could help undergraduate students to manage uncertain situations. Our specific research questions were:

- "In what ways does the use of Han *et al*.'s taxonomy of uncertainty support health professions educators' understanding of this concept when used experientially to support faculty development?"; and,
- "What do health professions' educators consider as key attributes for undergraduate learners with respect to managing uncertainty?"

To the researchers' knowledge, it is the first time that that this conceptual framework has been used in an educational setting to generate a deeper understanding of uncertainty in a context of faculty development.

METHODS

STUDY DESIGN

We used a qualitative study design that was informed by a constructivist methodological approach, where understanding about uncertainty was co-constructed by participants, using simulated scenarios as triggers for conversation and exploration of this concept[38]. This study is reported in accordance with O'Brien *et al*.'s Standards for Reporting Qualitative Research[39].

INTERVENTION

he faculty development session was underpinned by a social constructivist theory of learning. Using this approach, participants were encouraged to share meaning around the nature of uncertainty in health professions' education. The specific instructional design of the intervention was inspired by Armitage-Chan and Whiting's[40(p.360)] use of role-play to provoke faculty discussion around student professionalism learning outcomes, with an overall objective of helping attendees to "practice, reflect on, and develop important skills in a predictable and safe learning environment".

Each session was 90 minutes in length and attendees were notified of two learning outcomes, i.e., that, by the end of the session, they would be able to (i) analyse uncertain situations using a recognised taxonomy of uncertainty, and (ii) identify attributes that could help prepare undergraduate health professions' students to navigate uncertain situations. There were three components to each session: opening plenary (30 mins); focus group work (30 mins); and final whole group work (30 mins).

In the opening plenary, JM addressed contemporary definitions of uncertainty and highlighted early findings from a scoping review which explored how undergraduate health professions' students learned to engage with uncertainty which had been carried out by three members of the research team (JM, JH and TP)[14]. This was followed by a description of Han *et al*.'s taxonomy of uncertainty[29].

Next, the participants were invited to engage in a focus group activity. Participants had been pre-assigned to a group by facilitators according to profession, so that each focus group had a multi-professional profile. Group sizes ranged from four to six participants. In these focus groups, participants were presented with two role-played scenarios which they observed and discussed in sequence.

The role plays were scripted using content from first-hand student accounts of uncertainty documented in the literature[41,42], and enacted by experienced facilitators (Table 1). A live role

play was used during the face-to-face focus group, and a pre-recorded video role play was used during the online focus group.

Table 1: Uncertainty role play scenarios

Scenario 1
This conversation takes place in a quiet room off a ward in a busy teaching hospital. A clinical educator meets with final-year medical student Alice (right), who is on a general medicine rotation. Alice has just returned from a difficult interview with an elderly patient who was admitted to the ward with symptoms of pneumonia. *(Adapted from: Steinauer, J. E., O'Sullivan, P., Preskill, F., ten Cate, O., & Teherani, A. (2018). What Makes "Difficult Patients" Difficult for Medical Students?. Academic Medicine, 93(9), 1359-1366.)* Available online at: https://rcsi.cloud.panopto.eu/Panopto/Pages/Viewer.aspx?id=bf0c2b6a-d8fb-4067-8373-aba600a86cfa
Scenario 2
This conversation takes place in a small group teaching room of a university. Two first-year nursing students are attending a problem-based learning (PBL) session that takes place during a module on infectious disease prevention. The guidelines and facilities provided for the activity are less than optimal, and Dena (right) is confused. *(Adapted from: Biley, F. and Smith, K. (1999). Making sense of problem-based learning: the perceptions and experiences of undergraduate nursing students. Journal of Advanced Nursing, 30(5), pp.1205-1212.)* Available online at: https://rcsi.cloud.panopto.eu/Panopto/Pages/Viewer.aspx?id=72807b43-baa6-4e56-84c0-aba600a84cad

In the first scenario, participants watched "Alice", a final-year medical student, disclose her uncertainty when, during her hospital placement, her patient's unexpected communication and behaviour made her feel uncomfortable, limiting her capacity for clinical history-taking. The role play captures her debrief with a clinical tutor. Participants were asked to analyse Alice's experience using Han *et al.*'s taxonomy as a guiding framework, i.e., "If you place Alice at the 'locus' of uncertainty here, what sources and issues of uncertainty existed for her?" The participants were then asked: "What knowledge, skills or attitudes might have helped Alice to manage uncertainty in this situation?"

In the second scenario, participants watched "Dena", a first-year nursing student, discuss her uncertainties around a poorly organised problem-based learning (PBL) session with a fellow student. Again, participants were asked to apply Han *et al.*'s taxonomy, this time with Dena at the locus of uncertainty. They were also asked to consider what knowledge, skills or attitudes might have helped her to manage uncertainty.

After both scenarios had been observed and discussed, participants were invited to reconvene as a large group. Participants in the group were then asked to contribute to a list of knowledge, skills and attributes that could help undergraduate health professions' students to prepare for uncertainty more generally.

PARTICIPANTS

The faculty development intervention was offered on two occasions, with two distinct recruitments of participants. The first session was offered as part of the Irish Network of Healthcare Educators' annual conference[43]. The session was promoted to all conference attendees through the conference website and programme. The second session was offered to members of staff at RCSI, a health professions-specific university with an international campus (RCSI, 2000). This online session was promoted through email lists and the university's in-house social media platform (WorkVivo; Cork, Ireland), and was facilitated using Zoom web-conferencing software (Zoom; San José, USA). Participants in both sessions were informed that they could take part without being included in the research study. To qualify for inclusion in the study, participants needed to have an active role in supporting learning for health professions' students, and to have provided consent for their comments to be captured. There were no specific exclusion criteria. No incentives were offered to take part in this study.

The faculty development sessions were attended by 30 participants, and all attendees chose to take part in the study. The face-to-face session had 14 participants (13 female, 1 male; three focus groups): eight medical educators, three pharmacy educators, two dentistry educators, and a medical education researcher. The online session had 16 participants (13 female, 3 male; three focus groups): five pharmacy educators, two medical educators, two pre-clinical sciences lecturers, two health professions' education administrators, one physiotherapy educator, one nursing educator, one physicians' associate educator, one psychology lecturer and one simulation educator.

Researcher characteristics

All members of the research team have expertise across health professions' education, workshop facilitation and qualitative methodologies. JM is a faculty developer with a research interest in uncertainty in health professions' education. EAC is a faculty developer with expertise in professional identity. JH is a veterinary educator with a research interest in students' management of uncertainty. SK is a clinical medical educator with a research interest in assessment methods. TP is an educationalist with expertise in clinical communication skills, role play-based training and several decades of experience as a principal investigator in health professions' education studies.

Data collection

Data were collected in a range of different formats. First, group artefacts, i.e., flip chart pages (face-to-face focus group) and shared presentation slides (online focus group), were captured, and text was extracted from these. Second, focus group discussions were audio-recorded (face-to-face focus group) or video-recorded (online focus group) and these were transcribed. Finally, field notes were kept by facilitators during the focus group discussions.

Data analysis

Data from both study cohorts, face-to-face and online, were combined. Text from the focus group artefacts and from the transcribed discussions were organised using NVivo 12 (QSR International; Melbourne, Australia). Data were examined using a two-stage, hybrid approach of deductive and inductive thematic analysis based on a process proposed by Fereday and Muir-Cochrane[44]. In the first stage, JM created a coding framework based on questions that participants were asked to discuss in their focus groups which drew on Han and colleagues' taxonomy of uncertainty[29]. These were:

- What sources of uncertainty exist here for Alice?
- What are the substantive issues of uncertainty that Alice faces here?
- What knowledge/skills/attitudes might help Alice manage uncertainty here?
- What sources of uncertainty exist here for Dena?
- What are the substantive issues of uncertainty that Dena faces here?
- What knowledge/skills/attitudes might help Dena manage uncertainty here?

Data were categorised by the researchers according to each question using themes and sub-themes. In the second stage, the data were examined again by JM using an inductive approach; this was carried out to screen for unexpected themes which may have been relevant to our research questions. The application of the coding framework to the dataset was discussed by JM, JH and EAC, and the findings of the analysis overall were discussed by all members of the research team.

RESULTS

Data analysis of the focus group interactions revealed four themes overall. Three themes related to categories that had been pre-determined by the coding framework: "Sources of uncertainty," "Issues of uncertainty," "Uncertainty attributes" (Table 2). One further theme was identified as a result of our second stage of inductive analysis: "Learning environment" (Table 3).

Table 2: Identified themes (deductive analysis)

	Locus of uncertainty: Alice		Locus of uncertainty: Dena	
Theme	**Sub-theme**			
Sources of uncertainty for the student	Probability	• This patient interview may, or may not, have an impact on Alice's academic progress • Alice may, or may not, learn from this situation	• Dena's learning around the problem-based learning (PBL) topic may, or may not, be compromised • Dena may, or may not, miss out on an opportunity to learn from her colleagues in a team setting	
	Ambiguity	• Alice isn't able to fully engage with the patient meaning that the patient history is incomplete • There is a specific lack of details around psychosocial information concerning the patient • It is not clear whether or not the patient's response is a symptom of a psychiatric disorder • There is a lack of trust in information related to consent, i.e., "Is this the right patient?"; "Is consent in place?" • Alice lacks clear options on how best to proceed, i.e., stay with patient or exit? which communication skills to use? • Alice lacks clear information on how she will be assessed on this interview	• PBL is a teaching and learning strategy which naturally incorporates elements of ambiguity • There is a lack of induction to PBL and why it is used • There is a lack of instructions as to the specific task, e.g., details around goals, student roles, learning outcomes • There is a lack of clear guidance as to how assessment will take place	
	Complexity	• The patient's situation and presentation are inherently complex • Consent and capacity to consent are complex concepts • There appears to be a rapid change in the patient's condition which culminates in withdrawal of consent • Alice experiences tension between two roles: a student who will be assessed *and* a healthcare professional, i.e., "How will this reflect on me?" versus "How am I to proceed in managing this patient?" • Alice's apparent lack of experience and/or training adds difficulty to the situation	• PBL is an inherently complex teaching and learning strategy • The students are in their first year and lack experience with PBL • The environment, e.g., room set up, was not conducive to successful PBL session • Key people, e.g., the facilitator and other group members, are absent from the session • Dena is balancing the priorities of different tasks, i.e., engage with the PBL session or study for an anatomy test	

Table 2: Continued.

Theme	Sub-theme	Locus of uncertainty: Alice	Locus of uncertainty: Dena
Issues of uncertainty for the student	Scientific	• Alice is not sure if this is the right patient • She is not sure if consent is in place • She cannot fully interpret the patient's narrative or presentation • She is not sure how to approach the patient, or what to do or say; she is "bogged down in uncertainty" • She lacks clarity on whether to proceed with the interview or to exit • She struggles with how to apply her communication skills training in this particular setting • She is not sure how to change course when things don't go to plan	• Dena is disoriented by the teaching approach overall • She lacks information about the benefits of PBL • She is not sure how to proceed with the task • She is not sure why she would engage with the task, or why it's important • She lacks clarity on how to gain reputable information to complete the task • She lacks a clear connection between this task and how it links back to the end goal of her education
	Practical	• She does not trust that the system around consent has been followed correctly • She not sure which role is most important within this educational setting, her role as a student or her role as a healthcare professional • She is unsure of the role of the healthcare team, and how to interact with them, in the care of this patient • She doubts the relevance or effectiveness of the communication training she has received to-date • She is not sure if, or how much, she should disclose about the situation to her tutor • She is unsure about how the assessment process works here	• She is unclear of the role of the facilitator and who is "in charge" • She is unclear of the role of the other group members and what to expect of them • She doesn't know when, or if, the tutor is coming back • She doesn't know who her group is, or where they are • She is unsure about how this group task will be assessed • She is unsure which task to prioritise: engage with the PBL session or study for the anatomy test • She lacks clarity about the attendance policy for this session, and she doesn't know whether to stay or leave • Her efforts to engage with the task are hindered by lack of access to resources, e.g., effective Wi-Fi
	Personal	• She is not sure if she has the knowledge that she needs to handle this situation • She wonders why the communication skills that she has learned aren't working for her • She has concerns around the consequences for her ("How will this reflect on me?"; "Am I going to get in trouble?") • She has specific concerns around the consequences of this situation on her grades • She doubts herself with regards to how her approach with the patient ("Have I made a mistake?") • She experiences upset, anger and/or frustration as a result of the situation	• She is not sure what her responsibilities are in this situation • She is confused as to why she's not getting more support from the teaching staff • She feels a lack of trust in the facilitator and other group members • She is not sure if she wants to do this task; she experiences a lack of motivation • She experiences anxiety and a lack of confidence in her ability to retrieve solid information • She has concerns about how she is going to be marked • She has concerns about the fairness of the assessment process

Table 2: Continued.

Theme	Sub-theme	Locus of uncertainty: Alice	Locus of uncertainty: Dena
What knowledge/ skills/ attitudes might help the student to manage this uncertainty?	Knowledge	• More knowledge of this specific patient's medical history • Boundaries (i.e., knowing when to stay and when to go, knowing what to put up with) • Help-seeking (i.e., knowing when/how to ask for help, knowing your team and who to call, knowing limits of capabilities) • Consent and capacity • The importance of the patient (i.e., knowing to place the patient at the centre of the learning) • The nature of uncertainty: "It's not personal"	• More knowledge about PBL, its purpose and value • Uncertainty is part of the process in PBL • More knowledge about the specific session (e.g., the outcomes required, the specific assessment methods) • More knowledge about the her classmates and facilitator, and their roles and potential issues affecting them • More knowledge about the PBL topic and its importance • How group work takes place • How the session fits with the end goals of Dena's profession • The nature of uncertainty: "It's okay to not know"; "Sometimes the answers aren't going to be perfect"; "Sometimes there is uncertainty and it's just part of the process and you just have to go with a path")
	Skills	• Communication skills (e.g., recognising psychosocial issues, attending to nonverbal skills, giving patients space to tell their story) • Managing difficult interactions • Empathy • Assertiveness • Emotional regulation (e.g., meditative strategies) • Self-awareness • Resilience • Reflective processes • Cooperation • Teamwork • Problem solving • Insight • Taking initiative	• Communication skills • Self-directed learning • Teamwork • Research skills • Problem solving skills • Information retrieval skills • Project management skills • Decision-making despite incomplete knowledge
	Attitudes	• Openness • Adaptability/Capacity to change course • Collaborative attitude • Professionalism • Acceptance of patient difficulties • Showing an interest in learning • Growth mindset • Positivity • Confidence/Experience	• Openness to new ideas and processes • Motivation • Respect for others • Value learning from others • Growth mindset • Positive outlook

Table 3: Identified theme (inductive analysis)

Theme	Sub-theme	Locus of uncertainty: Alice	Locus of uncertainty: Dena
Learning environment	Reducing uncertainty	• Providing more information around assessment and how marking will happen in the context of a difficult situation	• Having trained faculty, moderating process for assessments • Providing expert high quality content and resources; having a third party proofread instructions • Provide preparatory session about the nature of PBL and the need to develop this skill • Have teaching staff experience a PBL session themselves • Nurture trust in the environment
	Role of the educator	• Importance of educators as role model in challenging situations • Tolerant student/supervisor relationships	• Calibrating expectations between staff and students
	Evidence-based teaching strategies	• More practice of difficult patient scenarios/awkward conversations • Simulation as an approach to prepare students and develop these skills • Debriefing and exploring the student's uncertainty, where the challenge arose. Why they chose their course of action? • Learning opportunities which integrate communication and teamwork	• Knowing the importance of buy-in – explain to students why PBL is used • Appealing to students' values or personal drivers • Thinking about the group dynamics
	Addressing the culture around uncertainty	• Normalising uncertainty for students	• Rewarding students for engaging with uncertainty • Signposting to students that managing uncertainty is part of maturing as a health professional

Sources of uncertainty

Using Han *et al*.'s taxonomy of uncertainty as a guide, focus group participants discussed many different sources of uncertainty for the students in the role played scenarios. These sources were categorized by the researchers into sub-themes which reflected the taxonomy: probability, ambiguity and complexity.

For example, participants noted how the future indeterminacy of events, or probability, could provide a source of uncertainty for the student. In the case of the clinical student, Alice, the participants talked about the different ways in which the situation could unfold for her:

> "*She does express an uncertainty about her grading and how she will be perceived based on that interaction although it wasn't clear unless the woman complained, she probably wouldn't get into trouble.*" [Medical education researcher, female]

Participants also shared ideas about how a lack of clear or trustworthy information (ambiguity) contributed to uncertainty in both scenarios:

> *"There seems to be an ambiguity in terms of the grading process as well, so that might be another source."* [Medical educator, male]

> *"They had been given a lecture, I suppose, but they don't really know where to find the information or are unsure where to find the information."* [Medical educator, female]

Discussions also highlighted aspects of the situations which made it harder for each student to understand (i.e., complexity). For example, participants picked up on the tension experienced by Alice in balancing her identity as a medical student with that of a new healthcare professional:

> *"So for the student, the greater consequence is 'How will this reflect on me?' as opposed to 'What are the issues for the patient?' So the student has the dilemma of having to fulfill both roles, one, in how they're performing and being assessed, and, two, as a... as a physician, even in their early days, 'How am I to proceed in managing this patient?'"* [Medical educator, female]

Finally, there were occasional instances where participants expressed confusion as to what aspects of the students' experiences could be classified as sources or issues.

> *"OK. So where would... that fall? Would that fall in issues or sources?"* [Focus group facilitator]

> *"No idea. I'm very uncertain around this." [laughing]* [Health professions' education administrator, female]

Issues of uncertainty

Our participants were also able to identify different issues of uncertainty for each student which were organised by the researchers into sub-themes according to Han *et al*.'s taxonomy [29]: scientific, practical and personal.

With regards to scientific, or data-centred, issues, participants observed how the situation had led to specific knowledge gaps for the students around their learning experience:

> *"She wasn't sure whether she should sit, she should sit on the chair to the... she should stand up closer to the patient on the bed? So she didn't know*

how to approach this patient." [Clinical educator, female]

"It's their first encounter maybe with PBL so... very disorientating for people who are used to conventional, didactic teaching. Very disorientating." [Medical educator, male]

There were multiple comments which related to how the system around the student, or practical issues, represented specific issues of uncertainty:

"And it wasn't until later on she started questioning was the patient consented, is this the right patient? Surely there should have been a process there to make sure all of that had happened at the outset? [Pharmacy educator, female]

"... they were given a task but no tools on how to do it. They weren't given the tools." [Medical educator, female]

Finally, participants were able to discern different ways in which the impact of these uncertainties could be experienced by students from a personal perspective. Personal issues of uncertainty that were mentioned included:

"You can see that in this situation her self-doubt was really kicking in." [Pre-clinical sciences lecturer, female]

"It was something about her lack of understanding kind of made her, again, uncertain of how to proceed or what to even look at. That was... a source of anxiety for her." [Simulation educator, female]

Uncertainty attributes – role-play specific

Our third theme, uncertainty attributes, stemmed from a section in the session where participants were asked to discuss what knowledge, skills and attitudes may have helped students to manage uncertainty within the context of the specific role play (Table 2).

With regards to knowledge, participants highlighted that more background knowledge of the topic at hand, e.g. a better patient history for Alice or a better understanding of MRSA for Dena, could have helped the students. They also listed specific types of knowledge for each student. For example, they considered that Alice could have benefited from more knowledge around setting boundaries and knowing when and how to ask for help, whilst Dena could have benefited from more knowledge about PBL, its purpose and value.

The participants also commented that the students might find it useful to have more insight around the nature of uncertainty in health professions' education:

> *"Sometimes you just have to go with a path."* [Physician's associate educator, female]

> *"It's okay to not know..."* [Pre-clinical sciences lecturer, female]

Participants listed numerous skills that could have helped these students. Notably, communication, teamwork and problem-solving skills appeared relevant to both Alice and Dena. Similarly, many attitudes were discussed with openness, growth mindset and positivity/positive outlook observed across both lists.

Learning environment

The final theme that was identified was "Learning environment." This theme covered a range of different comments which addressed participants' perspectives on how the learning environment could play a role in the uncertainty experienced by these students, or other students in similar situations. The comments were categorised according to four sub-themes: "Reducing uncertainty"; "Role of the educator"; "Evidence-based teaching strategies"; and, "Addressing the culture around uncertainty."

The first sub-theme focused on the ways that uncertainty in the learning environment can be reduced for students:

> "*If you're running a course, it's very important to make sure that all the guidance documents and the resources are available and arranged and provided in a logical order. So maybe it's a good idea sometimes to get somebody who's not directly involved to proofread everything, you know, as a fresh eye just so that, um, things are optimal for the students coming in*." [Health professions education administrator, male]

The next sub-theme highlighted the importance of the educator and educator-student relationships in helping students to navigate such uncertain situations.

> *"I suppose that maybe the tutor is available or it might be that they feel they can report back uncertainties. You know... as educators we say "if you've any problems come and tell me sooner rather than me hearing about it at the end of the week"... do you know?"* [Medical educator, female]

> *"It's important to have role models where they actually see somebody*

> *dealing with this difficult situation. It's all very well to talk about it in a room, but to see a skilled physician like [focus group participant] dealing with it…"* [Medical educator, male]

One participant highlighted how the taxonomy would help her to be more open to students' experience of uncertainty:

> "*When I first saw it without understanding the framework, I was just thinking, good God, she's so negative. It was just a judgment. Whereas actually now that I'm understanding more about uncertainty, it probably was a vulnerability on her part rather than the negativity. And that probably happens with a lot with students*." [Pharmacy educator, female]

The participants also outlined how evidence-based teaching strategies could have helped the students to feel more prepared for the situations they faced. For example, greater opportunities to practise and get feedback on challenging situations was mentioned:

> *"I suppose just what might help Alice… more practice, I suppose on those kinds of scenarios in the simulation environment I think first. If… if she hasn't got a chance to do that, you know, somewhere safe?"* [Physician's associate educator, female]

A final sub-theme addressed how the culture around uncertainty in health professions' education could be acknowledged and explored with students.

> *"You know, if that could somehow be rewarded or reflected or captured or somehow… Like reward uncertainty, if that makes sense? Like say, 'Uncertainty is a good thing. You should have it, you should share it. We should work on it. It's an important skill.'"* [Pharmacy educator, female]

Attributes

Finally, our participants were asked to contribute to a list of attributes, knowledge, skills and attitudes, which they considered would provide a foundation to undergraduate health professions' students in managing uncertain situations. These included an awareness of the nature of uncertainty within healthcare practice (i.e., "health professions' work has many grey areas as opposed to black/white ones"; "uncertainty is not always bad"), an ability to recognise uncertainty, and adopting attitudes of adaptability, positivity, and resilience. A full list of proposed uncertainty management attributes is presented in Table 4.

Table 4: Knowledge, skills and attitudes which support undergraduate health professions students to manage uncertain situations

Knowledge
• Core medical knowledge (e.g., consent topics) • How to define boundaries • How and when to escalate care or call for help • Knowing what to do when you don't know what to do • The purpose and value of teaching strategies (i.e., "priming" for learning) • An awareness of others' issues and roles (e.g., other classmates and patients) • The centrality of the patient in healthcare • The nature of uncertainty within healthcare practice (i.e., "health professions' work has many grey areas as opposed to black/white ones"; "uncertainty is not always bad") • Dunning-Kruger effect
Skills
• Recognising uncertainty • Communication skills • Managing challenging situations • Emotion regulation • Self-assessment • Self-directed learning • Working with feedback • Reflective practice (e.g., journaling) • Assertiveness • Taking initiative • Teamwork skills • Problem solving • Research skills • Information retrieval skills • Project management skills • Decision-making despite incomplete knowledge • Ethical decision-making
Attitudes
• Openness • Adaptability • Motivation • Value learning from others • Growth mindset • Positivity • Self-awareness • Collaborative attitude • Tolerance • Resilience • Engagement • Trust • Confidence/Experience

DISCUSSION

Revisiting our research question, we reflect on the ways in which Han *et al*.'s taxonomy can support health professions educators' to better recognise and conceptualise uncertainty. The findings from this study indicate that this taxonomy of uncertainty can be pragmatically applied to a faculty development setting. Specifically, the framework allowed participants to achieve a greater depth of understanding around students' experiences of uncertainty than they might have achieved had they worked without it.

Using the taxonomy, participants were able to identify multiple sources and issues of uncertainty for the students, thus unveiling the extent of uncertainties encountered by health professions' learners in relatively commonplace circumstances. Whilst it may seem paradoxical to want to unpack an experience of uncertainty into further, multiple uncertainties, this can be an important opening step to managing such situations. As noted by Han *et al*.[29(p.2)], "uncertainty is not a monolithic phenomenon. There are multiple varieties of uncertainty, which may have distinct psychological effects and thus warrant different courses of action." By recognising and teasing out the separate sources and issues, educators can identify, or help students to identify, more adaptive responses to uncertainty.

It was also considered that the taxonomy worked well in the focus group setting. Previous studies that have used Han *et al*.'s taxonomy to organise experiences of uncertainty have tended to describe one-to-one approaches such as in-depth interviews[31,34,35]. To the authors' knowledge, this is the first time that the taxonomy was used in a group setting. The level of detail provided by the participants around the students' uncertainties was surprisingly high and suggests that using the taxonomy in a group setting, where individuals hold different personal responses and perspectives, can uncover a more complete range of sources and issues of uncertainty. Perhaps this process, beyond the taxonomy itself, stimulated reflection on what constitutes 'good' management of uncertainty or, indeed, 'good' teaching around management of uncertainty?

This was also the first time, to our knowledge, that the taxonomy was applied to simulated rather than real-life experiences. We chose this approach as we considered it a low-risk way of introducing educators to student uncertainties. In practice, this took the form of a perspective-taking exercise, where educators were asked to focus on the students in the vignettes. There was some evidence that this approach helped educators to develop more open approaches to student uncertainty; one participant described a greater empathy towards one of our role play students as a result of engaging with the taxonomy. This is an important faculty development issue, considering the salience of the educator-student relationships in mitigating the uncertainties that students encounter in the course of their studies.

Overall, we consider that this framework provides a valuable tool for faculty to approach conversations around uncertain situations. As Han *et al.*[33(p.924)] explain, the taxonomy has an important function in "promoting shared awareness of otherwise unconsidered sources and issues of uncertainty, and enabling stakeholders to approach these uncertainties in an organized manner." In the context of education, this taxonomy can provide an entry point and guiding framework, promoting dialogue around uncertainty that might otherwise be avoided. The taxonomy could also be used to help educators and students engage in shared reflection around the specific sources and issues of uncertainty in any given situation, facilitating shared mental models and improved decision-making processes.

Whilst most of our data related to the taxonomy and activities used in the intervention, our analysis also revealed a theme around how the learning environment contributed to the uncertainty experienced by these students. Despite being asked to focus on the knowledge, skills and attitudes that could help these students, the discussion often drifted towards what the participants might have done differently in organising teaching. The issues highlighted were: reducing uncertainty for the students, the role of the educator, using evidence-based teaching practices, and addressing the culture around uncertainty. This digression from the task at hand may have resulted from the choice of role plays; in both cases there was a perception that students had been let down by some level of failure in their education. Alternatively, this might have represented participants' efforts to prevent uncertainty from arising in teaching, rather than acknowledging that students will likely experience uncertainty as part of their learning experience.

Our study revealed that participants, when faced with this in-depth and extensive appreciation of uncertainty within the scenarios, tended to respond in different ways. There were responses that were oriented towards students' learning and development (e.g., using these to make explicit the nature of uncertainty to students, and defining the skills to cope with such situations). However, there were also responses that were oriented towards reducing or removing the uncertainty for the student, with many suggestions as to how to "fix" the situations that Alice and Dena found themselves in. A drive to reduce uncertainty has been well documented within the health professions' practice. As Han *et al.*[45(p.275)], say: "Physicians and other health care providers manage these effects and their experience of uncertainty itself through various strategies, but principal among these is the effort to seek information to reduce uncertainty. Nearly every major clinical activity that physicians undertake—diagnostic, prognostic, and therapeutic—is part of this overarching effort." However, our findings here suggest that that this drive to reduce uncertainty extends beyond clinical activities into those of teaching.

Whilst reducing uncertainty for students and patients is important, it may not always be possible, or, indeed, the right course of action. The value of identifying these uncertainties

is not so much that they can be prevented by preparing the student, but more that they can be used as focal points for reflection and discussion, supporting the student to manage, respond to and cope with uncertainty. In this study, participants did seem to recognise that there are times for educators to step in and times to step back. For example, it may be appropriate to reduce uncertainty for students at specific points in their training e.g., to support them as they enter clinical rotations or during first exposure to problem-based learning, with a gradual 'stepping back' of this supervisory management of the environment, being replaced by exposure to uncertainty. It is likely that such a scaffolded approach to uncertainty can be approached practically through shared reflective strategies where students and tutors employ tools such as the taxonomy used here[46].

Within the theme of learning environment we also noticed the appearance of a more positive, accepting narrative around the culture of uncertainty. Past research has highlighted that uncertainty can be viewed from a negative perspective by educators and students[14]. Here, participants commented that uncertainty should be highlighted as normal and "a good thing", and that development of skills to manage uncertainty can be viewed as part of the maturation process within undergraduate health professions' education. This may suggest that faculty development interventions, such as the one described here, can promote a 'stop and reflect' approach for educators, i.e., encouraging them to pause to consider, and communicate to students, the importance of productive uncertainty in the learning process.

Our second research question enquired as to what health professions' educators considered as key attributes for undergraduate learners with respect to managing uncertainty. When asked to consider the knowledge, skills and attitudes that could help our role play students, and undergraduate health professions' learners more generally, to manage uncertainty, the participants listed multiple and diverse attributes. Here we will focus on the more general attributes (Table 4) as these were deemed of greatest relevance to our research question.

Perhaps somewhat unsurprisingly, our participants considered that having a firm foundation in core medical knowledge would help reduce uncertainty for health professions' learners. They also commented that it would be helpful for students to have a greater understanding of their role, as well as that of their colleagues and the patient, in healthcare settings. Some comments related to the nature of uncertainty and how it would benefit students to understand that uncertainty is "normal" and "not always bad" in healthcare. Other additions to the list, i.e., "knowing what to do when you don't know what to do", served to reinforce how even experienced educators have difficult pinning down specific, observable steps to help students in managing uncertainty.

With regards to skills that may help students to manage uncertain situations, these included communication, emotional regulation, problem solving, information management, ethical

decision-making and an ability to self-assess. Each of these skills are supported within the existing health professions' literature[14]. Again, there were additions to the list, e.g., "taking the initiative", that were more vague and harder to define. One addition to the list, "recognising uncertainty" was of particular interest. Whilst we know that health professions' learners meet uncertainty in multiple stages of their training, it's likely that many learning opportunities are missed. The literature signposts that experiences of uncertainty commonly happen "under the radar" in healthcare settings, e.g., Mackintosh & Armstrong[47(p.13)] highlight that "uncertainty work… may not be directly experienced or categorised as such by those undertaking it." This leads us to ask if it may be helpful to prime both educators and students to notice when uncertainty emerges in the course of learning. It may be that using a "lens" of uncertainty to explore difficult situations could be a useful approach in the context of shared educator-student or student-student reflections.

Finally, attitudes thought to be helpful in managing uncertainty were: openness, adaptability, positivity, and a growth mindset. Again, these have been supported in the literature[48-50]. Although student attitudes are typically viewed as more difficult to expand on, such 'intangibles' can be developed experientially and through structured reflection, e.g., through small group 'debrief' tutorials or personal journals.

STRENGTHS AND LIMITATIONS

A key strength of this study is the successful application of Han *et al.*'s taxonomy[29] to a faculty development session, opening the door to further explorations of its use within educational contexts. We consider that the taxonomy is a practical and versatile framework which can help to empower health professions' educators when working with students to manage uncertain situations derived from real-life experiences. Whilst this study uses the taxonomy to focus on the perspective of a student (i.e., the student as the locus of uncertainty), our intervention could be easily adapted to explore the uncertainties faced by educators and clinicians from a wide range of socio-cultural and professional backgrounds. We also consider that overall instructional design of this session could be adapted to the context of undergraduate health professions' education, providing a valuable opportunity for students to diagnose and classify aspects of uncertainty that they meet during their training.

Although there were occasions where the participants expressed confusion with regards to the sources and issues of uncertainty, these were not frequent, and did not appear to detract from the utility of the tool overall. On this basis, we recommend Han *et al.*'s taxonomy as a conceptual framework of interest, which has potential application in a wide variety of uncertainty management educational interventions.

The study also resulted in a list of knowledge, skills and attitudes which can be used in discussions around how to manage uncertainty in the context of health professions'

education. Our list of attributes, whilst not exhaustive, can be used by educators and students alike in considering how best to work with, or respond to, an uncertain situation.

There were, however, several limitations associated with this study. Our study sample size was small, and, due to the opt-in nature of both faculty development sessions, it's likely that participants held some pre-existing interest in uncertainty management. Further to this, almost all participants were based at health professions' education institutions in Ireland. Individuals' approaches to uncertainty can be heavily influenced by professional and socio-cultural variables[51-53], and, thus, our findings may not be representative of the views and experiences of a more diverse faculty cohort.

In addition, offering the intervention as part of a conference setting added time restrictions to its design. Participants were presented with just two role-played scenarios which aimed to balance depth of enquiry with feasibility. More time, and a greater number and diversity of scenarios, may have yielded different results. Finally, we believe that any future delivery of a similar intervention should include the active participation of health professions' students. Our focus in this study was the development of faculty and our intervention design used a perspective-taking approach, i.e., our participants were asked to consider uncertainty from the viewpoint of a student. Whilst we consider this approach was a valid way to provoke thought and discussion around uncertainty attributes, it would have helped to have health professions' students take part in the facilitation of the session to bring real-world depth to our role-played scenarios.

CONCLUSIONS

This study highlights the successful use of Han *et al.*'s taxonomy of uncertainty within a faculty development setting. The taxonomy provides an effective conceptual framework which educators can use to identify a wide range of sources and issues of uncertainty for students within simulated scenarios. Our findings suggest that Han *et al.*'s taxonomy is a practical and versatile tool in designing faculty development interventions around uncertainty management. Participants in this study also contributed to a list of uncertainty attributes, i.e., knowledge, skills, and attitudes, which may be useful to undergraduate health professions' learners in managing uncertainty. Finally, our findings suggest that health professions' educators can sometimes feel compelled to reduce or remove uncertainty for students, which may not always be the most appropriate course of action. We propose that more faculty development in this domain is likely to be required.

DECLARATIONS

Ethics approval and consent to participate

This study received ethical approval from the RCSI Research and Ethics Committee, RCSI University of Medicine and Health Sciences (Ref: REC201912005). All participants gave written consent to take part in the study. All methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication

The authors affirm that RCSI staff members have provided informed consent for publication of the video recordings in Table 1.

Availability of data and material

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no competing interests to declare. We certify that the submission is our original work.

Funding

Internal funding from HPEC (Health Professions' Education Centre), RCSI University of Medicine and Health Sciences was provided for this study.

Authors' contributions

JM and EAC conceptualised the study. JM, EAC, JH, SK and TP contributed to the study design. JM, EAC and JH led the data collection and analysis with support from TP. JM produced the first draft of the paper; all five authors contributed to and refined this draft. All five authors approved the final manuscript for submission.

Acknowledgements

We would like to express our sincere gratitude to Dara Cassidy, Andrea Doyle, Jan Illing, Brian Marron, and Mary Smyth for their help in this research study. Thank you also to Paul Han who gave feedback on a draft version of this paper.

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Building a digital educational escape room using an online design-thinking process

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Published in: Online Learning Journal. 2023; 27(2), 223-244

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ABSTRACT

There is increasing interest in the application of game-based learning approaches to education. Educators across a wide range of contexts are using digital games such as educational escape rooms to promote learner motivation and support skills development. Whilst the literature describes multiple game-based learning theories that can underpin such strategies, there is little practical guidance on how to integrate such conceptual elements into the design of digital educational escape rooms. This study aims to address this gap, outlining the use of an online design-thinking process to plan, build, and test a digital educational escape room.

Our findings suggest that this process provides an effective way of harnessing team collaboration and innovation in the development of digital educational resources. The process provides structure for game design teams, enabling them to address complex or "messy" educational development problems. In utilising an online design-thinking process to design games for learning, we make a number of recommendations. These include taking time to establish psychological safety within the design team so as to facilitate creative team processes, and supporting team members to adopt a design-thinking mindset throughout (e.g., regularly taking the perspective of the game user, and testing game prototypes early and frequently).

Finally, our study offers a detailed description of how the online design-thinking process can be applied in an education context with the aim of offering guidance to educators and students who may want to design, build, and test their own digital educational escape rooms.

INTRODUCTION

The use of games, specifically digital games, in educational contexts has been identified as an important emerging trend[1,2]. Game-based learning is increasingly used to promote learner motivation and improve the quality of the learning experience for students in a wide range of contexts, including online settings[3-5]. Game-based learning can involve students in game-making as well as game-play, and an increasing body of research focuses on the capacity of game design to support higher order learning such as creativity and critical thinking[4,6].

Despite the growing evidence base behind game-based learning, it can be difficult for online educators to incorporate such approaches into their teaching. Whilst educators may be aware of the wide variety of educational theories relating to game-based learning[7-9], they often lack clear guidance on how to apply such conceptual elements in designing online educational games. Furthermore, there are few frameworks or models that support educators to use game design in online learning contexts[10].

To address this gap in the literature, our study explores the use of an online design-thinking process to design, build, and test a type of digital game known as an educational escape room. To the authors' knowledge, this is the first study that examines the development of an educational escape room using design-thinking methods mediated entirely within an online environment. First, our article offers a review of the literature relevant to online education, game-based learning, digital educational escape games, and developing educational games using design thinking, followed by details of our research questions. Second, we present a detailed description of our study design and, in particular, the online design-thinking methodology that was used. Third, we present the results of testing an initial digital educational escape room prototype. Fourth, we discuss these results alongside the applications of online design thinking for building digital games.

REVIEW OF RELATED LITERATURE

ONLINE EDUCATION

The fostering of interaction and communication within learning communities is a foundational concern of online education[11]. From its roots in distance education, the theory of transactional distance[12] captured the "psychological and communication space" that emerges between teacher and learners[13(p.2)], when they are separated physically and sometimes temporally. High levels of transactional distance require learners to exercise greater levels of autonomy in order to succeed, while learning environments that facilitate a high level of dialogue (constructive interaction) between teacher and learner serve to decrease the transactional

distance[12]. Although the theory has been criticised for its failure to operationalise the key constructs[14,15], the notion of transactional distance is still recognised as an analytical framework that can be used to understand the dynamics of online distance education systems[15].

The Community of Inquiry (CoI)[16] focuses on the elements that support the development of a collaborative online learning environment, and is a well-researched, empirically tested framework within which to plan and research online education[17]. The CoI focuses on three types of presence that have been shown to be critical in online education—social, teacher and cognitive. Social presence refers to individuals' ability to project themselves as real people, and thus provide a basis for meaningful interpersonal interaction in the virtual world. Teaching presence refers to the actions an instructor takes to guide students along their learning journey (e.g., through dimensions of instructional design). Cognitive presence relates to the extent to which the participants in a learning community are able to construct meaning through sustained communication. It is the goal toward which social and teaching presence are directed, and a manifestation of higher-order learning in the online environment[18].

The CoI emerged at a time where interaction within the community of learners was largely asynchronous. However, more recently, the widespread adoption of video conferencing platforms has opened new avenues for synchronous online engagement as a central modality[19]. It has been suggested that synchronous formats may be more suited to socialising and engaging in less complex tasks and planning activities[19,20], while asynchronous modes are better suited to more challenging group activities that require reflection[19-21]. However, media-rich synchronous environments can be used to facilitate deep learning[22,23]. Online educators are advised to factor in the subject matter, learning outcomes, and learner characteristics when seeking to determine the appropriate mix of synchronous and asynchronous activities[19].

GAME-BASED LEARNING

Game-based learning can be defined as "an environment where game content and game play enhance knowledge and skills acquisition, and where game activities involve problem-solving spaces and challenges that provide players/learners with a sense of achievement"[24(p.51)]. In recent years, the growing acceptance of digital games as mainstream entertainment[25,26] coupled with an increasing focus within education on transversal skills has led to an enhanced interest in the application of game-based learning approaches in education[27]. A growing number of studies highlight the capacity of digital games to promote motivation and engagement; facilitate learner-centred feedback; provide opportunities for role play, practice and rehearsal of skills; and foster collaboration, problem solving, and critical thinking[28-30].

Digital games are particularly suited to online learning settings. Effective online learning is interactive, flexible, and facilitates connections between educators and peers[31]. Digital games for learning, if designed well and applied appropriately, can uphold many of these characteristics. Furthermore, games which harness social-constructivist or constructionist learning theories can help meet some of the challenges encountered in online learning environments (e.g., student isolation and lack of engagement)[32,33]. Game-based learning can be employed at multiple different levels, and there is a growing recognition of the value of involving students in the design of educational games[29,34]. Through learning by doing, game design offers students routes to deep learning, and opportunities to engage with authentic problem-solving and creative processes[24,34,35].

DIGITAL EDUCATIONAL ESCAPE ROOMS

Educational escape games, also known as escape rooms or breakout games, are an increasingly common way for educators and students to engage with game-making[36]. Originating from the entertainment industry, escape games can be defined as a "live-action, team-based game where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal... in a limited amount of time"[37(p.1)]. When used for educational purposes, the escape game goals are aligned with learning outcomes for players.

In recent years educational escape games have transitioned into online settings, and are often referred to as digital educational escape rooms (DEERs). DEERs are used in a wide range of settings to address many, varied learning outcomes[38,39], and have proved a popular way of facilitating active and team-based learning during the Covid-19 pandemic[40,41]. In the literature, DEERs have been linked to different educational theories including cognitivist, constructivist, and socio-cultural approaches to learning[27,42]. Although research in this domain is in its infancy, escape games are thought to support the acquisition of knowledge, as well as the development of team-building, problem-solving, and communication skills[42].

DEVELOPING EDUCATIONAL GAMES USING DESIGN THINKING

Digital games such as educational escape rooms offer opportunities to improve the quality of online learning experiences[4]. However, their incorporation into learning environments requires a thoughtful, theory-based approach that reflects the often complex cognitive, emotional, and motivational mechanisms involved[43]. Educators must understand the variety of pedagogical and game design considerations involved in building engaging game-based environments[44]. Support and guidance is necessary when integrating game-based learning in online environments[29].

Design thinking offers an established framework for building digital games for learning[6]. Defined as a "way of finding human needs and creating new solutions using the tools and

mindsets of design practitioners"[44(p.24-25)], design thinking offers a structured process for teams to engage in collaborative, creative work[45]. In recent years, the approach has been used extensively in the development of educational escape rooms, both physical[46-48] and digital[49,50]. Design thinking may hold particular value for online educators as the process can be mediated entirely within virtual settings[51,52]. Online design thinking has emerged rapidly across a wide range of online learning environments and contexts[52,53].

However, surprisingly few studies explore the use of online design thinking in the development of digital games for learning. Whilst the literature provides several examples of the use of face-to-face design thinking to build *physical* educational escape rooms[46,47], there are none, to the authors' knowledge, which examine the use of online design thinking to build *digital* educational escape rooms. This represents an important knowledge gap for online educators, and one that our study seeks to address. Thus, our research questions are:

- How can an online design-thinking process be used to design, build, and test a digital educational escape room?
- What are users' experiences of a prototype digital educational escape room developed using online design thinking?

METHODS

This study forms part of a larger design-based research project that aims to explore how medical students can be supported to manage uncertainty during their undergraduate education. Design-based research offers a flexible approach which allows researchers to design and test educational resources in a naturalistic settings, whilst simultaneously advancing our understanding of relevant theoretical frameworks[54]. Design-based research projects can be organised broadly according to three phases: preliminary research, prototyping, and assessment and reflection[55]. This study focuses on the prototyping phase, specifically the first design cycle of the project and a small-scale usability study. The study employed qualitative data collection and thematic analysis methods in order to uncover rich contextual data around the game users' experiences[56].

CONTEXT

In 2021, researchers at RCSI University of Medicine and Health Sciences received funding to design, build, and test a digital educational escape room that aimed to help medical students to manage uncertainty. The focus of the escape room was on supporting students during transitions from pre-clinical, college-based work to clinical placements in hospital settings, an experience that is frequently recognised as stressful and anxiety-provoking[57]. A design team was enlisted to build the escape room, and medical students at RCSI, a culturally diverse, international health sciences university with over 4,000 students from 90 different

countries, were invited to take part. The core team consisted of ten medical students (six female undergraduate medicine students; three male undergraduate medicine students; one female graduate-entry student) and one educationalist based in the university's faculty learning and development unit. Team members joined from five different countries across three continents.

INTERVENTION

We used an online design-thinking intervention to design, build, and test our digital educational escape room. This intervention followed the five-phase process of design thinking proposed by the Hasso Plattner Institute of Design at Stanford University[58]: empathise, define, ideate, prototype, and test. The project ran over a nine-week period in the summer of 2021, and, during this time, a further 26 medical students, two educational escape room researchers, three medical education professionals, two design professionals, two illustrators, one medical uncertainty researcher, and an audio-visual professional were invited to contribute.

Prior to commencement of the design-thinking process, the lead researcher [JM] developed a high level brief for the project, which delineated how it was intended to support attainment of specific learning outcomes. Informed by socio-cultural theories of how learners engage with and support each other, the educational goal of the escape room was to introduce the topic of uncertainty in healthcare, and create conditions that would enable game users to experience uncertainty, and explore the processes by which they supported each other as they progressed through the game. Subsequent to completion of the game, a debriefing session would be used to trigger reflection and offer theoretical inputs to scaffold learners' ability to manage feelings of uncertainty.

The lead researcher created a purpose-built online space that was housed on a Moodle virtual learning platform (Moodle HQ; Perth, Australia). This online environment held details of the project schedule, project aims, online meeting links, weekly activities, team contact details, and acted as a repository for collaborative teamwork and project documentation. Online teamwork and communication was facilitated by several technologies including Zoom (San José, USA), Miro (San Francisco, USA), Padlet (San Francisco, USA), and WhatsApp (Meta; San Francisco, USA). Prior to initiation of the design-thinking process, a series of online activities (e.g., ice-breakers, discussion, and games) were held so as to establish psychological safety and a design-thinking mindset within the group. During these opening online meetings, the team discussed the project design challenge: How might we use a digital educational escape room to help medical students manage uncertainty during transitions into the clinical setting? Overall, we aimed to create an online educational resource that would help medical students to manage uncertainty, with a timeline of nine weeks and a budget of €2,000 to create a prototype.

Empathise

The aim of the first phase of design thinking is the development of a deep understanding of the design challenge and whom it affects. During early discussions, the team identified activities and people that could help them to build insight. We carried out a review of the academic literature with a specific focus on uncertainty and medical students, medical students' experiences of transitions from pre-clinical to clinical environments, and educational escape rooms. We also invited content experts to team meetings to further probe these research domains. As a result, we identified gaps in our knowledge such as, "How might an escape game help users to better manage uncertainty?"; "Is it important or useful for users to experience uncertainty during game-play?"; and, "How can the game provide education as well as entertainment?" The team also engaged in discussions which aimed to define our audience for the escape room (i.e., the game users). The audience was primarily defined as pre-clinical medical students, although other relevant stakeholders were identified including clinical medical students, clinical educators, and patients. We spent time reflecting on the diverse nature of medical student cohorts with different socio-cultural and language backgrounds, and varying degrees of interest in, and confidence with, technology-enhanced learning.

We then explored game users' perspectives through a series of empathy interviews. Empathy interviews are a common design-thinking activity which aim to help design teams find out as much as possible about the user's experience with respect to a problem, process, or context. To complete this task, the design team co-constructed a question guide and used this to interview medical students who had recently transitioned from pre-clinical to clinical education. The design team set out to learn more about the students' experiences, address knowledge gaps, and invite advice as to how a DEER may be of value in the context of clinical transitions. The empathise stage of design thinking also invites teams to immerse themselves in the problem and gain inspiration through carrying out fieldwork or observations. To do this, our design team played a variety of online escape games that ranged from simple, online educational games[59], through to more sophisticated commercial games[60,61].

Define

The second phase of design thinking involves transforming information gathered during the empathise phase into meaningful insights. To do this, the design team engaged in a series of individual and group reflections that included an affinity mapping exercise, a design activity which helps teams to organise large volumes of mixed data into themes or clusters. This activity helped the team to identify themes and scenarios around uncertainty that had emerged from interviews and could be suitable for prototyping. The affinity map was constructed using a mind-mapping software (Miro.com; San Francisco, USA) and resulted in a persistent artefact that could be re-visited at any stage of the project.

The define stage of design thinking also asks teams to reflect on further "How might we…?" questions. In our project, questions that emerged included "How might we make a game that addresses the needs of undergraduate medical students whatever their background and culture?" and "How can our game be made accessible regardless of the user's experience or confidence with digital learning technologies?" During the define stage, the team proposed a list of draft educational learning outcomes for the DEER, and a set of design principles that could influence design of the game. With respect to the latter, we considered that DEERs that aim to support learning around uncertainty could benefit from:

- An engaging and consistent storyline
- Game goals that align with intended learning outcomes
- Gameplay which supports authentic shared reflection
- Contextualisation of gameplay with appropriate pre-briefing and de-briefing
- Game flow which involves an easy puzzle ("quick win") at the start
- Puzzles that trigger affective experiences of uncertainty for players

Finally, we explored a range of pedagogical theories and strategies that could inform how learning might take place for the game users, including social constructivism, shared reflection, and the Community of Inquiry framework[16].

Ideate

During the ideate phase, design teams generate and refine ideas that may be relevant to the design challenge. To do this, our team engaged in separate stages of divergent (coming up with as many ideas as possible) and convergent (ranking, sorting, or narrowing ideas down) thinking. We generated and refined ideas with respect to multiple different game elements, including the narrative, game-flow, and puzzles, using an escape game design framework[62].

In devising a DEER theme, the design team broke into small groups and were asked to create a vision board using images that represented the "look and feel" of a DEER that would align with medical students' experiences of uncertainty. The vision boards were created using Padlet (San Francisco, USA) and the teams presented these to each other for feedback and discussion. Then, between sessions, team members were asked to reflect on the discussions and submit ideas for themes anonymously through a shared online document (Google Docs; Alphabet; Palo Alto, USA). At the next session, the design team reviewed the themes and ranked them in order of preference. The team was subdivided into small groups and asked to advance ideas for the two top themes. This was achieved through a storyboarding exercise, facilitated through Miro.com (San Francisco, USA) (Figure 1). The team discussed the different storyboards, and key ideas from each were synthesised into a draft DEER narrative. This draft narrative was shared with team members who were invited to add and make changes to the story.

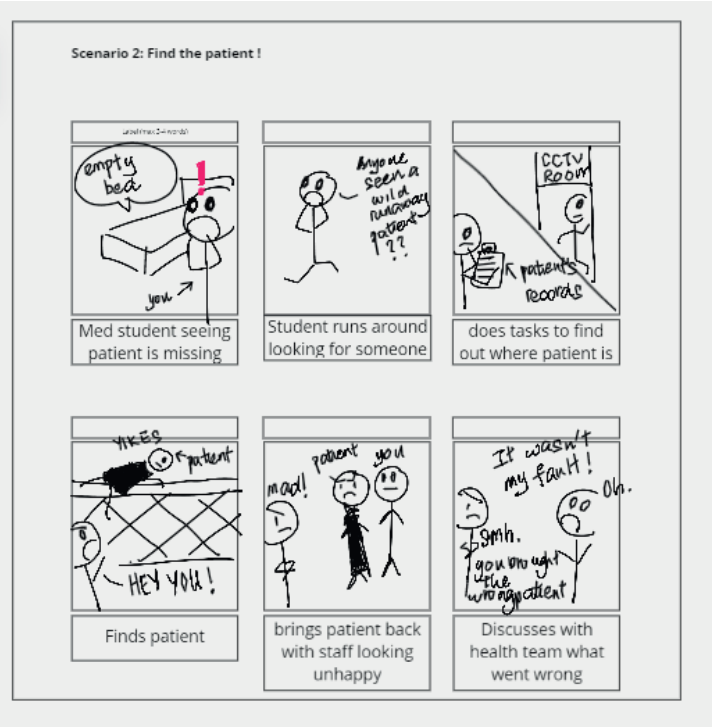

Figure 1: Detail from storyboarding exercise

In developing puzzles, design team members were assigned to the game learning outcomes using an educational blueprint. Each team member created one or more puzzles and used a reflective template to outline puzzle features (i.e., puzzle type, difficulty, game outcomes, and hint and reward strategies). Team members then play-tested and gave feedback on each other's puzzles. The team selected the puzzles that they felt were most engaging and aligned best with the DEER learning outcomes. The design team then split into small groups and advanced the chosen puzzles. Finally, the design team play-tested this iteration of puzzles

Prototype

Design thinking is a bias towards action over discussion (i.e., ideas are tested early and frequently through the creation of prototypes). Storyboards and models allow the design team to explore how well, and in what way, their efforts address the design challenge. To test our initial concept, the design team built a prototype DEER on an online interactive content editor platform (Genially; Madrid, Spain). Puzzles were selected and placed in sequence on the platform. The final puzzle selection was cross-checked with the educational blueprint, ensuring that the game learning outcomes were addressed. A puzzle flow chart was

created to provide a visual overview of the prototype and the game users' pathway (Figure 2). Finally, the team decided on topics to address during the pre-brief and de-brief aspects of the game-play session.

The resulting prototype consisted of a 10-puzzle game built on the Genially platform. The overall theme for the game was that of a clinical medical student navigating through a creepy, dream-like hospital setting, and a basic storyline was presented through a game character's reflective journal. The puzzle structure was branched or path-based[37], and involved a variety of puzzles, including numerical, word-based, logic, and general knowledge. Each puzzle had an associated hint. This prototype was designed to be used by small groups of players (4-6), who would work collaboratively in online break-out rooms to solve puzzles and earn clues towards a final meta-puzzle. The prototype lacked a developed storyline or sophisticated audio-visual content.

Figure 2: Puzzle flow chart

Test

The testing phase of design thinking asks users to engage with a prototype and elicits their feedback. The aim is to find out what works and why at an early stage of the process, and most design-thinking processes involve multiple stages of testing and refinement. In our project, the testing phase represented a small-scale usability study which aimed to explore game users' experiences of the Genially platform and the puzzles (e.g., quality, difficulty, and overall flow). Details of the testing stage are provided below.

PARTICIPANTS

All medical students enrolled at the university were eligible to take part in testing, and recruitment took place through online, student-led social media channels. In addition, content experts who had taken part in the scoping aspect of the design-based research project were invited to test the prototype. Participants were arranged into play-test groups. There were no specific exclusion criteria, and no incentives were offered to take part in the study.

DATA COLLECTION AND ANALYSIS

In July 2021, the prototype escape room was play-tested with participants. There were two methods of data collection. First, the participants were arranged into small groups of 4-5, and asked to play the prototype game using a concurrent think-aloud protocol[63,64]. In accordance with this method, participants were asked to describe their experiences verbally as they interacted with the game[65]. Game-play took place following a short pre-brief (5 minutes) and was followed by a de-brief (15 minutes). During each play-test session a facilitator was present; the facilitator's role was to remind the participants of the think-aloud process and offer help if game-play stalled. The play-test facilitators also collected field notes that captured written observations of the users' interactions with the game.

Second, participants were invited to share their opinions on their game-play experiences in focus group discussions that took place immediately after play-testing. Focus groups were facilitated by experienced researchers, and the question guide sought the participants' experiences of the game itself, the puzzles, and their learning around uncertainty. Participants were also given the opportunity to provide advice to improve the prototype.

Both the think-aloud sessions and focus groups were facilitated through Zoom web-conferencing software (San José, USA). All sessions were video-recorded, and the audio component of each was transcribed by JM. Qualitative data from both the play-test sessions and the focus group discussion were combined and explored using reflexive thematic analysis[66]. The researchers used an inductive approach to identify codes and themes within the data. The transcriptions were read and re-read several times, and any comments that related to the research questions were noted, resulting in a set of opening codes. These codes were then organised into initial themes. As analysis continued, these themes were refined, re-organised and then allocated a name. The results of this thematic analysis are presented below.

RESULTS

Seventeen students (11 female undergraduate medical students, three male undergraduate medical students, three female graduate entry medical students) agreed to test the prototype and were assigned to four play-test groups. Five content experts (two female escape room researchers, one male game-based learning researcher, one female uncertainty researcher, one male uncertainty researcher) also agreed to take part and were assigned to two further groups. The following research questions guided researcher engagement:

> *Research question 1: How can an online design-thinking process be used to design, build and test a digital educational escape room?*

The results of this study suggest that online design thinking offers an effective approach in the development of digital educational escape rooms. Here, the online design-thinking process resulted in a 10-puzzle game built on a Genially (Madrid, Spain) platform, which was play-tested by six groups of users. All groups reported that the game functioned well, and the platform was deemed easy-to-use and intuitive by the users. All groups were able to progress through the game, although only four out of the six groups completed the escape room within the allocated time. For the groups that did finish, the average duration of play was 59 minutes, with a range of 49 minutes to 1 hour nine minutes.

> *Research question 2: What are users' experiences of a prototype digital educational escape room developed using online design thinking?*

Four major themes emerged from the qualitative data analysis: (1) positive aspects of the prototype, (2) negative aspects of the prototype, (3) support of learning, and (4) suggestions for improvement.

POSITIVE ASPECTS OF THE PROTOTYPE

Overall, the game users reported many positives about the prototype game and highlighted that it was a fun experience. The main aspects of the game that they enjoyed were working as a team and engaging in challenging puzzles. Game users were also positive about the theme of the escape room, and that it presented a "good representation" of experiences of medical students on clinical placements. They also liked the "feel" of the game, the "creativity" of the storyline, and found the artwork attractive and professional. With regards to the puzzles, game users reported that there was a good variety and mix of difficulty levels. They liked certain aspects of puzzle sequencing; for example, the users appreciated an opening puzzle that was relatively easy. Finally, the game users were largely positive about the Genially platform. They reported that it was intuitive, easy-to-use and, overall, supported teamwork during the game.

NEGATIVE ASPECTS OF THE PROTOTYPE

Game users also identified several negative aspects of the prototype. For example, there were a range of technical issues such as puzzles glitches, spelling errors, and broken links which they considered had interrupted the "immersivity" of the experience. With regards to puzzles, two were thought to be "under-challenging" with "predictable answers." It was also considered that there were too many word-based puzzles (e.g., anagrams), and that such puzzles could be especially challenging for non-native English speakers. Game users also suggested that the platform could be more interactive and use more sophisticated game elements (e.g., addition of augmented or virtual reality).

SUPPORT OF LEARNING

With regards to learning around uncertainty, users reported that there were moments within game-play that they felt "helpless" and "uncertain," and agreed that the game-play effectively provoked these affective experiences. For some, game-play facilitated insights such as "going with your gut," "being comfortable with being uncomfortable," and "it's good to share." Other users reported that they had failed to learn about uncertainty during game-play. They made recommendations that the game would benefit from stronger links between puzzle content and the evidence base around uncertainty.

With regards to other learning outcomes, the users reported that the prototype had supported them to engage in critical thinking. They considered that the game provided them with a "safe" environment to test ideas and engage in shared reflection. Multiple users mentioned that the game had helped them to appreciate the different strengths, skills, and perspectives of others.

SUGGESTIONS FOR IMPROVEMENT

Users also made suggestions for improvement of the escape room. With regards to puzzle design, they thought that there should be fewer word-based and general knowledge puzzles, and more visual or pattern-based ones. Clearer instructions should also be added to some puzzles. Several extra features were suggested including a progress bar, timer, and "scratch pad" to capture written team-work. Participants also thought that a different game strategy (e.g., time penalties or supplementary puzzles for incorrect answers) might help reduce the motivation for users to engage in guessing behaviour. Successful solving of each clue, and of the game overall, could be linked to a more explicit reward, for example, a message of gratitude from a patient. Game users also offered ways to improve the pre-brief (e.g., providing greater guidance over team roles as well as rules around using the internet to solve puzzles). Finally, game users expressed a preference for a richer audio-visual experience (i.e., improved graphics and the addition of videos and a soundtrack.)

Written observations

During play-testing, facilitators collected field notes. According to these written observations, all groups were able to progress through the game. Overall, the Genially platform functioned as expected and the users were able to click through puzzles and content with ease. There were, however, some issues that emerged during game play. For example, the hint strategy was not used by players as intended. Hints were provided to the game users through a map feature. Many groups failed to notice the map and, for others, its purpose was not clear and appeared to cause confusion. Furthermore, the groups that were aware of a hint strategy seemed reluctant to use this function; it is possible the presence of a facilitator during game-play may have had a negative influence on the game users' decisions to use the hint strategy, or to engage in guessing behaviour.

DISCUSSION

Our study set out to explore the use of an online design-thinking process to design, build, and test a digital educational escape room. The results of our first design cycle suggest that the online design-thinking framework supported the creation of a functional prototype educational escape room which was well-accepted by users. Overall, game users were positive about key game elements such as the platform and puzzles, and they commonly reported experiences of fun and enjoyment during gameplay. In addition, the users identified ways in which game-play had supported their learning around uncertainty through both cognitive and affective mechanisms, as well as the value of the game in promoting a "safe" space for teamwork. The users also offered guidance around how to advance the platform, puzzles, and other game elements which can be fed into further design cycles and iterations of the game. In addition, the study results appear to substantiate our initial digital educational escape room design principles.

Whilst our study aimed to evaluate the product of online design thinking, an educational escape room, our findings also offer insight as to the process of online design thinking and how it can be used to develop games for learning in online settings. Designing games and integrating these into online learning environments can be a "laborious and complex process"[67(p.367)]. When the development process itself is taking place in a technology-mediated context, a complex range of factors need to be considered to provide a holistic insight into the dynamics involved[68]. A strength of online design thinking is its capacity to structure such processes, helping game development teams to organise their activities and methods. Moreover, this approach promoted a high degree of dialogue and reduced the transactional distance[12] between students who were grappling with unfamiliar technologies and activities. Design thinking also appears to have helped to facilitate the development of an online community that in many ways mirrored a community of inquiry[16] with the

aspects of social, teaching, and cognitive presence clearly evident. Within this community, the educator could scaffold the overall learning experience for the students (i.e., teaching presence) who had little background experience of game design or game-based learning. Scaffolding has been shown to be particularly important in online learning environments, and educators are advised to reflect on students' needs, and to use appropriate, supportive learning resources and instructional methods[69].

Furthermore, online design thinking facilitated the creation of a structured blend of synchronous and asynchronous activities[19], with synchronous meetings used to brainstorm and exchange ideas supported by the use of collaborative white board[20,70,71] and the asynchronous Moodle virtual learning environment configured to support aspects of the projects that required deeper discussion and reflection[20,21]. This approach to online communication during the project seemed to facilitate team formation and break down perceived power hierarchies. This supports the notion that students' ideas can attain "greater equality, exposure and consideration" when online design-thinking processes are compared to those that take place in physical design studios[72(p.30).] The project also cultivated a sense of connection and camaraderie within the team (i.e., social presence) against the backdrop of a particularly difficult year defined by Covid-19 lockdowns and restrictions. Overall, these conditions supported our educator-student team to work together in a genuinely collaborative manner, overcome geographical distance, and to engage effectively with a "messy" design challenge.

Our experiences of online design thinking suggest that this approach offers a unique environment for testing educational games in naturalistic online settings. With its emphasis on human-centredness, design thinking keeps the needs of the user in the foreground as ideas and solutions are generated. Online design thinking, by its very nature, also keeps issues of technology and how learners operate in online settings in sharp focus. It appears that an online environment can offer more insight as to how a target audience may use a digital educational game, as compared to a face-to-face environment. This human-centred approach also meant that the design team engaged in critical thought around how the game could be designed to meet the needs of diverse students from different cultures, backgrounds, and familiarity with digital games for learning. When combined with frequent periods of prototyping and testing, this process led to a digital game that worked well in an authentic online learning setting and was well-received by its target audience.

Online design thinking is not, however, without its challenges. The process is time-consuming and resource heavy. Design teams need to harness expertise from a wide range of disciplines and backgrounds. In addition, careful team facilitation is required. Engaging in creative teamwork can be demanding, especially in online settings where nonverbal interpersonal communication is more restricted and where team members often connect

across socio-cultural, language, and time zone barriers. Online design educationalists have noted that design teams' social interactions can be harder to facilitate in online settings[73]. It is thus necessary to have design team leads who can generate a learning environment that supports effective communication and encourages individuals to share ideas and offer authentic feedback to each other. Finally, although design thinking can take place on minimal budgets, the process does benefit from some degree of funding. Here, our budget allowed us the freedom to explore different avenues (e.g., test out different escape games, enlist the help of graphic designers, and experiment with different technologies).

STRENGTHS AND LIMITATIONS

To our knowledge, this is the first study that explores the use of an online design-thinking process in developing a digital educational escape room. The process can provide insight to educators that would like to use this approach in their own teaching context. However, there are limitations to this study. It should be noted that our student design team had self-selected to take part in the study; thus they were likely highly motivated to take part in the online design-thinking process. Research suggests that students often engage with collaborative online learning interventions to different degrees; some students find it harder to connect online, share ideas, and engage in deep dialogues than others[74]. Our findings may have been different if a wider cohort of students, with varying levels of engagement, had participated. Furthermore, design thinking is a context-specific activity and, as such, further studies that examine its use in designing different types of digital games, in multiple and varied online settings, would be valuable.

CONCLUSION

This study set out to explore the use of online design thinking as a model to support educators in harnessing game-based learning and game design in their online learning programmes. In doing so, it viewed the challenge of creating an online design-thinking process in terms of a teaching and learning challenge, mindful of the complex web of elements that require consideration in technology-mediated learning contexts[75]. Overall, it was deemed that the design-thinking process worked well in the online setting. The approach proved an effective way of harnessing team collaboration and innovation within a geographically dispersed educator-student team, enabling them to address a "messy" educational development problem. Insights from this study may be helpful for educators, researchers or practitioners who want to use similar methodological approaches and co-create digital educational games with their students. In conclusion, we recommend the online design-thinking process as a strategy to design, build, and test online games for learning such as digital educational escape rooms

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to Ms Zara Ahmed, Dr Anique Atherley, Ms Catherine Bruen, Dr Naoise Collins, Dr Martina Crehan, Mr Harry Cummins, Mr Gareth Edwards, Mr Mark Ennis, Dr Heidi Eukel, Dr Michelle Flood, Ms Sarah Flynn, Dr Paul Han, Dr Jan Illing, Ms Lauren Li, Dr Ruth Little, Mr Ray Lohan, Ms Mary Smyth, Ms Julia Morris, Mr Aditya Patki, Ms Romket Pornsakulpaisal, Ms Shaudee Salari, Mr Goka Smruthik, Ms Vitallia Sooknarine, Dr Ellen Stuart, Dr Alice Veldkamp, Ms Yap Sook Woon and the medical students of RCSI for their support in this project.

DECLARATIONS

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval for this study was granted by the RCSI Research and Ethics Committee, RCSI University of Medicine and Health Sciences (ID: 202103004).

This project was supported by funding from the Irish Medical Council/INHED Research in Medical Education (RIME) Award, and from the RCSI StEP (Student Engagement and Partnership) Framework.

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Establishing psychological safety in online design-thinking education: a qualitative study

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Published in: Learning Environments Research: 1–19.

5

ABSTRACT

Design thinking, an approach traditionally used to develop or improve products, services, or processes within design and engineering sectors, has emerged as a novel pedagogical approach. As design thinking becomes more widely established within education contexts, it is important to gain deeper insight as to how such learning environments operate. The aim of this study was to explore online design thinking through the lens of psychological safety. We used a qualitative single case study design to investigate nine students' experiences across a nine-week design-thinking project.

Data were collected via semi-structured interviews and reflective journal entries, and analysed through reflexive thematic analysis. Our findings suggested that psychological safety is a valuable consideration in the design and implementation of online design-thinking learning environments. Facilitators of psychological safety included having collaborative environments, encouraging leadership, and a focus on team formation. Barriers to psychological safety included difficulties connecting, fear of speaking, and cultural considerations. Our findings also highlighted several outcomes of psychologically safe team climates including creativity, collaboration, and the development of approaches to working with uncertainty.

INTRODUCTION

Design thinking is a team-based approach to problem solving that is used to develop products, services, or processes in industries such as design and engineering[1]. In recent years, design thinking has been enthusiastically adopted across diverse higher education contexts, including business[2], computer science[3], information science[4], law[5], marketing[6], media[7], and medical education[8]. The approach has also crossed over with ease into virtual learning environments, with higher education students now able to learn about, and through, design thinking in a variety of online settings[9-11], a phenomenon catalysed by the recent Covid-19 pandemic[12,13]. Despite this surge of interest, there is limited research that investigates online design thinking, and educators have little guidance as to what constitutes "best practice" in this domain[14(p.1362)]. With higher education's increased reliance on technology, it is crucial that we use empirical methods to gain further insight as to how such novel learning environments operate.

Design thinking centres on "people not technology"[14(p.1362)], and design teams must be able to collaborate effectively in online settings. Existing learning environments research highlights the importance of interaction, both educator-learner and learner-learner, in the development of group processes in online settings[15,16]. Furthermore, online environments that nurture a sense of belonging and closeness between learners and teachers can provide fertile grounds for effective collaboration[17,18].

Studies have also highlighted the importance of psychological safety, i.e., "the degree to which people view the environment as conducive to interpersonally risky behaviors like speaking up or asking for help"[19(p.66)], in building connections within online learning environments[20,21]. Team members who experience psychological safety are thought to engage more readily in creative or innovative work[22-24]. Psychological safety has been studied in a wide variety of physical learning environments including clinical medical education[25], experiential learning[26] and simulation-based settings[27]. Although a growing number of studies are turning their attention to psychological safety in online learning environments such as digital gaming[28] and virtual debriefing[29], there appears to be a lack of research that explores its role in online design thinking. The aim of this study was to apply a lens of psychological safety to this novel pedagogical approach, and examine design team members' experiences of sharing ideas, making mistakes, taking risks, and discussing problems[22] in the online setting. Our research questions were: (i) can psychological safety be facilitated in online design thinking?; and, if so, (ii) what factors help or hinder the establishment of psychological safety in online design-thinking teams and (iii) what outcomes of psychological safety can be recognised.

METHODS

STUDY DESIGN AND THEORETICAL PERSPECTIVES

This pilot study forms part of a larger design-based research project that aimed to design, build and test a digital educational escape room that helps medical students to manage uncertainty. Design-based research (DBR) is "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings"[30(p.6)]. Importantly, DBR projects allow researchers to design and test developments or interventions in naturalistic settings, whilst also advancing understanding of contemporary theoretical issues[31]. Here, adopting a DBR approach allowed us to explore the online design-thinking learning environment through the lens of psychological safety whilst developing a practical educational resource. We used a qualitative single case study design[32] that was grounded within a constructivist paradigm[33]. The study has been reported in accordance with Tong et al.'s[34] Consolidated Criteria for Reporting Qualitative Studies.

CONTEXT AND PARTICIPANTS

In the summer of 2021 an online design-thinking project was hosted at RCSI University of Medicine and Health Sciences, a culturally diverse, international institution with over 4,000 students from 90 different countries. The project was facilitated by the university's StEP (Student Engagement and Partnership) initiative, which aims to promote staff-student collaboration. One staff member and one final-year medical student led the project, and nine further student places on the design team were advertised through online, student-led social media channels. The project was open to all medical students enrolled at the university, and participants were selected purposively via submission of a written personal statement that probed students' interest in, and experience of, digital game-playing.

Over a nine-week period, the design team followed a five-phase process of design thinking[35] to address the design challenge: "How might we use a digital educational escape room to help medical students to manage uncertainty during transitions into the clinical setting?" Each week, the full design team met online for a synchronous "design huddle" facilitated by web-conferencing software (Zoom; San José, USA). During these sessions, team members engaged in a wide range of design activities including theme building, story boarding, puzzle making, and affinity mapping. Between the full-team sessions, the students met in small groups, allocated according to their broad geographical location (North America, Europe, Asia) to engage in further design activities, including game-user interviews, escape game sessions, and game testing. Finally, the students also took part in individual activities such as puzzle making and journal writing throughout the duration of the project. Online design activities were facilitated by several technologies including Miro (San Francisco, USA), Padlet (San Francisco, USA), and Moodle (Moodle HQ; Perth, Australia).

Overall, the five-phase design-thinking process resulted in the development of a prototype digital educational escape room. All nine students on the design team were invited to take part in this study on a voluntary basis. All students agreed to take part and provided their written consent

ETHICAL APPROVAL

This study received ethical approval from the RCSI Research Ethics Committee (ID 202103004).

DATA COLLECTION

The study used methodological triangulation[36] by gathering data through two methods: semi-structured interviews and reflective journal entries[37] (Figure 1). The semi-structured interviews were held in the final week of the project, and used an interview guide that incorporated questions aligned to existing measures of psychological safety[38], and was developed in accordance with suggestions made by Kallio et al.[39]. The interviews were conducted by a facilitator not connected to the study with the aim of reducing the likelihood of students giving responses that "the interviewer wants to hear"40(p.881). Interviews were held online with a duration ranging between 25 and 60 minutes. These were video-recorded and the audio component transcribed. The weekly journal entries, submitted through Microsoft Forms (Redmond, USA), captured the participants' reflections on their experiences using trigger questions such as: "What are you feeling at the start of this project?"; "How would you describe the team climate or atmosphere on this project so far?"; "What are you learning about your own responses to uncertainty in this project so far?" These journal entries allowed participants to share perspectives on the project within a different context and across a longer time-line, aiming to avoid a "snapshot" approach to data collection[40(p.883)].

DATA ANALYSIS

The data-sets derived from the transcribed interviews and the journal entries were combined and organised using NVivo 12 (QSR International; Melbourne, Australia). The data were analysed through reflexive thematic analysis[41], an approach which allows researchers to identify themes that are "conceptualised as patterns of shared meaning underpinned by a central organising concept"[42(p.39)]. This entailed a six-phase process: familiarisation with the data; coding; searching for themes; reviewing themes; defining and naming themes; and, writing up. The researchers used an inductive approach to identify codes and themes within the data. However, deductive analysis was also used to ensure that codes and themes were relevant to all three of our research questions. The researchers used both semantic and latent coding to analyse the data, and it was possible for data to be double-coded. The analysis was primarily conducted by JM with input from RL in sense-checking codes and themes.

In the first phase, JM read and re-read the data several times to familiarise herself with the content. Notes of potential codes, initial trends and negative cases were made on printed versions of the data. Second, JM generated initial codes using an open-coding approach, making several passes through the data. Third, JM and RL explored the content of the codes with the aim of identifying candidate themes that could express their common content, and assess their relationships between codes and themes. During this phase, codes were also revised where necessary. Fourth, the themes were modified and codes were re-organised resulting in some themes merging and others re-named. This resulted in an initial set of themes and sub-themes. Fifth, the themes were defined and named by identifying the "essence" of what each theme was about. In the sixth and final phase, we revisited the research questions, notes, and codes, to ensure that the final themes represented a close match with the original data, and could be mapped back to the initial research questions with accuracy. The final themes and sub-themes identified through the analytical process are presented in the results below (Figure 2).

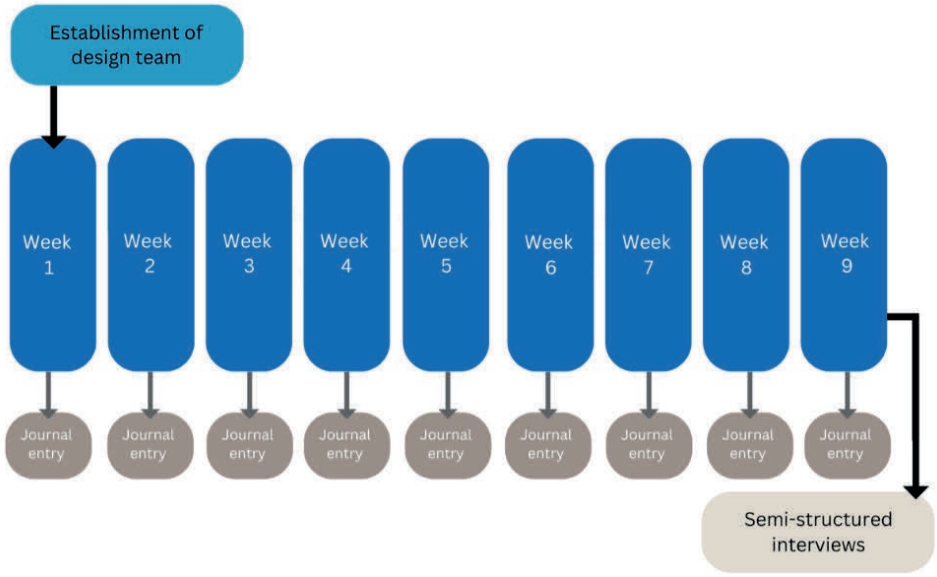

Figure 1: Study design flowchart and data collection

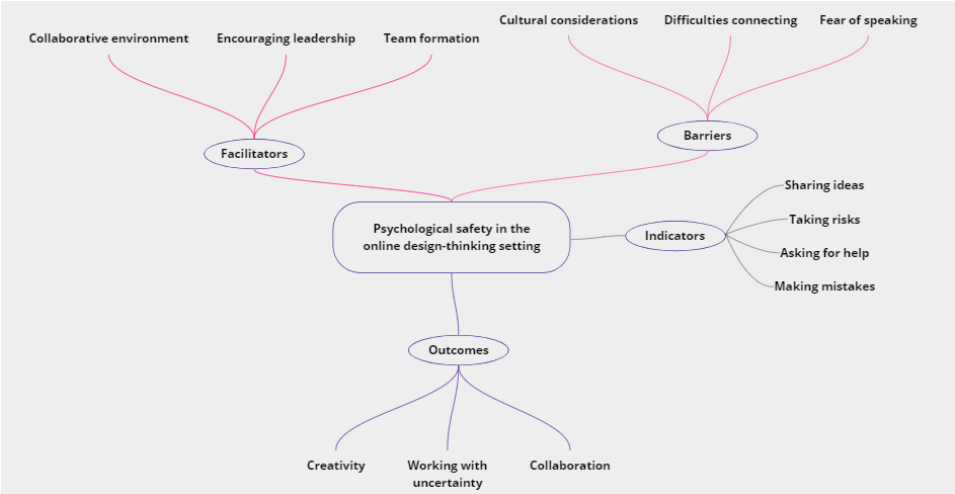

Figure 2: Themes and sub-themes identified through the analytical process

RESULTS

Nine participants (five female undergraduate medical students; three male undergraduate medical students; one female graduate-entry medical student) engaged in the weekly journal activities, resulting in 51 unique pieces of reflective writing. Eight participants took part in the semi-structured interviews (one participant was not available).

The data were analysed with respect to the research questions (i) can psychological safety be facilitated in online design thinking?; and, if so, (ii) what factors help or hinder the establishment of psychological safety in online design-thinking teams and (iii) what outcomes of psychological safety can be recognised? , and the following themes and sub-themes were identified:

- indicators of psychological safety (sharing ideas, taking risks, making mistakes, asking for help);
- facilitators of psychological safety (collaborative environment, encouraging leadership, team formation);
- barriers to psychological safety (difficulties connecting, fear of speaking, cultural considerations); and,
- outcomes of psychological safety (creativity, collaboration, working with uncertainty).

INDICATORS OF PSYCHOLOGICAL SAFETY

Data analysis suggested that psychological safety can be facilitated within online design thinking (research question 1), with several indicators of the construct recognisable within

the data. These indicators were categorised according to the sub-themes: sharing ideas; taking risks; making mistakes; and, asking for help. The participants spoke at length about the ease they felt in sharing ideas and opinions during online sessions. They felt comfortable taking part in team discussions and were able to offer alternative perspectives. They also felt safe to ask questions. Multiple comments related to how the participants felt heard by the rest of the team, and that their ideas were valued. Overall, participants expressed that they felt respected and understood.

> *"I felt like you could speak freely... and it wasn't like you know, sometimes you kind of throw ideas out and someone can kind of shut you down. I didn't feel like that's what it was. I felt like if you threw something out there, it was taken into consideration."* [SP445]

Participants also felt comfortable in taking risks during the intervention. They identified several aspects of online work that they considered "risky". These included speaking up during online sessions, offering creative work for evaluation, and sharing ideas. With regards to the latter, participants expressed a "fear of failure", (i.e., that their ideas would not be liked or deemed of sufficient merit by others). Despite these fears, the participants felt safe to "step outside of the comfort zone" and discuss ideas, even those that could have been considered unconventional.

> *"Any sort of weird, wacky, outlandish ideas or thoughts that we had, we would just say them. And there was no judgement from anybody else in the group... So anything that we said, even if it was a bit out of bounds, was still completely fine."* [SP836]

The participants also reported feeling safe to give, elicit and receive feedback, without feelings of criticism. They also felt equipped to offer suggestions for change and address mistakes within the project. The participants highlighted that making change was easy, and did not involve intense emotional frustration.

> *"So at one stage, we had to all send in puzzles, and then two other team-mates would look at it and give evaluations. Well, it didn't feel bad to ask 'OK, what can make it better?', 'What didn't work?', 'What could I change to make it easier for a player to understand?'"* [SP050]

Finally, the participants commented that they felt equipped to ask for help as they became more familiar with each other. They sought help both during the synchronous online sessions and via asynchronous channels. One participant highlighted that the safety she experienced within the project encouraged her to engage in "help-offering" as well as

"help-seeking" behaviour.

> *"If it weren't for [Facilitator 1] being so friendly and being so open to crazy ideas... I wouldn't have personally emailed her asking if, you know, she if she wants any help from me. Since I like doing art, maybe I could find illustrators or work with an illustrator to help create an illustration?"* [SP421]

FACILITATORS OF PSYCHOLOGICAL SAFETY

The participants highlighted several factors that could help the establishment of psychological safety in online design-thinking teams (research question 2). These were arranged into three sub-themes: collaborative environment; encouraging leadership; and, team formation.

There were many comments on the influence of the online learning environment. The participants spoke about the importance of the weekly, full-team online sessions in becoming more familiar with each other. They noted that "getting to know each other" was important with respect to building psychological safety. Regular ice-breakers (e.g., online polls and activities) were valued as helpful. They were also particularly positive about break-out rooms (i.e., technology that divides a large group of individuals into smaller, private sub-groups online) which allowed them to share ideas in a low-stakes way. One participant commented that she considered the number of people in the full-team sessions, normally 11-12 participants, as "massive". Another participant highlighted that choices around how to communicate during the full-team sessions (e.g., by using voice or text-chat communication and to keep cameras on or off) helped her to share ideas.

> *"Bonding with other group mates during either sessions or group work makes me feel more connected, and once I feel more connected then I feel more comfortable sharing and asking in the group!"* [SP246]

> *"Getting to know people better by interacting with them via the small group sessions... made me feel comfortable sharing my ideas and discussing more openly."* [SP330]

The participants highlighted that small group activities provided opportunities for more informal communication and relationship building. Social activities such as playing online games together were valued. In addition, they liked that the groups had been organised by time zone, which made synchronous communication easier.

The participants also spoke about the central role of the project facilitators in establishing psychological safety. A range of different leadership skills were mentioned, including

effective communication, keeping the team on task, and creating a safe space to draw ideas out. Specifically, the use of supportive language ("encouraging words") and communication approaches helped participants to feel validated. Facilitator attitudes of "openness" and "friendliness" contributed to the experience of psychological safety. Participants felt that such approaches helped them to transcend a perceived hierarchy between the student team members and the facilitators as "seniors".

> *"I think what helped is that [Facilitator 1 and 2] didn't make it seem like they were our seniors in a sense. They made us feel like we were all one group and we were all at the same level, we shouldn't be fearful of them in a sense, because sometimes, you know, you see heads of the project and it's kind of scary. But from the first day they established that, you know, this was a safe environment and they wanted to hear all of our ideas and that they really wanted us to pitch in."* [SP445]

Team formation was also considered important. The participants remarked that it took time to feel comfortable with each other. It was considered that a positive start to the project (e.g., through co-creating guidelines on how the team would work together) was helpful. They also commented on the open, supportive and non-judgemental communication of team members in both synchronous and asynchronous channels. Overall, team formation culminated in an atmosphere characterised by warmth, humour and informality.

> *"I think the biggest component to encouraging the sharing of ideas and creating a safe space is the atmosphere our group has created. From the beginning, we all agreed on a series of guidelines for open communication; it was nice being able to explicitly go over that. Going forward, all of our group members were friendly and encouraging. I believe that mentality made me feel comfortable speaking up and gave me a sense of ease."* [SP445]

BARRIERS TO PSYCHOLOGICAL SAFETY

Participants also described several factors that could hinder the establishment of psychological safety in online design-thinking teams (research question 2). These were arranged in three sub-themes: difficulties connecting; fear of speaking; and, cultural considerations. Participants highlighted challenges in building relationships in the online environment. Some felt that face-to-face meetings would have helped them to develop richer social relationships, as well as to progress more quickly through collaborative tasks.

> *"I feel like [a face-to-face setting] would have been be much more collaborative because you can sit around with each other and discuss with each other. And at the end of the day, when you're done with the work, you*

can just grab some coffee and then deepen your friendship." [SP330]

Others commented that it was difficult to engage in one-to-one conversations during the full-team sessions compared to a face-to-face setting. Having cameras off, noted several participants, could lead to a lack of engagement. Similarly, there were times when they struggled to find the right moment to enter into a discussion during synchronous conversations.

A fear of speaking in the online setting was also observed. Many participants mentioned a general nervousness about interacting online. Making comments, asking questions or using "raise hands" tools were all considered risky. The participants referred to a tendency towards "shyness" with regards to online meetings. Overall, the participants preferred small groups over large groups.

> *"I guess, I'm not like a super talkative person, so like even just like in during the workshop, like stepping out to just start talking is a step out of my comfort zone."* [SP246]

Finally, there were comments about how language and cultural differences may act as a barrier to the establishment of psychological safety. For example, one participant commented that being a non-native English speaker could interfere with her conversations with teammates. Cultural considerations concerning the formal or informal nature of communication were also highlighted, with one participant voicing hesitation about using more informal types of communication where the facilitators were involved.

OUTCOMES OF PSYCHOLOGICAL SAFETY

Finally, a number of outcomes of psychological safety were observed within the data (research question 3), and these were arranged into three sub-themes: creativity; collaboration; and working with uncertainty.

The participants noted how psychological safety helped them to engage in creative behaviour. They described a process where they felt safe to generate and share ideas. They were also able to build on each other's ideas, finding synergies in their work. Despite a sense that creative work was risky and at times difficult, the participants felt that they could overcome blocks in their imagination and sit with discomfort during the creative process.

> "*When I started, I was like, 'How are we going to do this?'... But it was just interesting to see how us doing these tasks every week... we just made this whole product and I was like 'Wow, I have no idea how this came together!?'"* [SP445]

The participants also highlighted that psychological safety helped them to collaborate more fully as a team. It was acknowledged that they often worked interdependently and autonomously during the project. They described being able to engage in problem solving and task switching with ease. They were also able to manage differences of opinion or conflict.

> *"I think there was definitely times where I was having a problem or there was something I couldn't figure out how to do, and I was able to get kind of feedback from like my other team-mates and they were like 'Oh, this person did this. Maybe you could try this?' or 'This was something that I had done and maybe this could help you figure this out?'"* [SP445]

Whilst there were many comments about uncertainty in relation to the overall goal of the design-thinking intervention, an online escape game that would help medical students to manage uncertainty, these were not deemed relevant to the research questions. However, the participants also discussed experiences of managing uncertainty within the design-thinking process itself. They noted many uncertainties including how the project would run, engaging in new activities, the workload involved, and the quality of their ideas and creative work.

> *"Every time we are tasked to do something new or unfamiliar (i.e., interviewing someone/ making a puzzle), I still get butterflies in my stomach. But as the project progresses, I realised I'm getting more comfortable with the tasks, especially with the help of my kind group-mates. The safe environment that this project provides also helps me deal with those uncertainties too."* [SP100]

> *"During this project my response to the arising uncertainties doesn't feel as anxious or nerve-racking as they usually do. I believe this is due to the comfort level I have developed amongst the group where I don't feel judged for my thoughts and ideas."* [SP445]

DISCUSSION

This study sought to provide insight on the role of psychological safety in online design-thinking learning environments. Our results suggest that psychological safety can be nurtured in such settings, enabling student design team members to share ideas, speak up and ask for help. The data also indicates that our participants experienced psychological safety despite perceiving multiple uncertain and anxiety-inducing moments when engaging in creative, team-based activities. Their excitement at taking part appeared to be tempered by apprehension, especially when exposing their ideas or work to others. Such experiences are commonplace when students engage in creative processes, and authors recognise

that "exploring new possibilities and producing novel ideas and behaviours" can evoke anxiety for some[43]. This extends to design-thinking settings that invite students to "abandon comfort zones"[44(p.306)] and engage with a wide range of emotions[45,46].

Our findings also suggest that students experience a sense of risk in relation to interacting online. Many participants expressed nervousness around offering ideas or asking questions during online synchronous sessions. Although they reported feeling able to speak up during online meetings, it took time to reach this state of psychological safety. This supports previous research that highlights students' discomfort with synchronous activities which require "spontaneous and skilled responses 'on the fly'"[47(p.11)], potentially exacerbating existing worries around social interaction and contributing to so-called "zoom anxiety"[48]. Our findings support the idea that although higher education students are often characterised as "digital natives", online learning environments may not, by default, represent natural habitats for all. It appears that online design thinking, which involves risky creative, team-based learning in a risky online environment, places students in a unique space of shared vulnerability. This reinforces the notion that psychological safety holds value for online design-thinking education, enabling design teams to collaborate effectively.

Whilst psychological safety appears simple, it is not easy to achieve[49], and effort is required in generating an environment where individuals feel empowered to raise concerns or ask questions. Newman et al.[50] highlight several antecedents of psychological safety including supportive leadership, team relationships and organisational practices. Our data support these factors and offer insight as to practical ways in which psychological safety can be facilitated in online design-thinking settings. For example, synchronous online sessions helped students to "get to know each other", a process that was deemed essential to establishing psychological safety. More specifically, break-out rooms facilitated the building of trust and relationships. The value of break-out rooms in establishing social connections has been highlighted by others[51].

The participants also spoke at length about the value of effective leadership. They indicated that team facilitators helped lay the foundations for psychological safety through attributes and skills such as openness and supportive communication. These findings mirror the broader literature that acknowledges "the salience of the direct leader in shaping the work context and crucial role leaders play in fostering psychological safety"[52(p.140)]. This becomes especially important when staff and students engage in collaborative design processes to the backdrop of hierarchical environments such as medical education[23]. Although participants expressed a comfort in working with the facilitators, they continued to use differentiating terms such as "seniors" to categorise them. This suggests that there may be scope to offer further communication options where the facilitators are not present, as this may lead to more fluid conversations between peers.

The role of the facilitator is particularly important in online settings. When students engage in face-to-face design-thinking projects they often operate in a physical design space with visual cues to help them transition into a creative mindset. Such visual cues are less available in the online setting, placing an onus on facilitators to "[set] the stage for creativity, encouraging the energy and social connection that makes in-person learning engaging"[14(p.1361)]. Furthermore, facilitators also need to help online design-thinking students to become confident users of technologies that are, at times, "unreliable, difficult and cumbersome"[53(p.349)]. It is likely that facilitators' verbal and non-verbal communication skills are of critical importance in addressing these challenges.

Another factor that can facilitate psychological safety is team formation. Our participants noted that an investment of time and effort in setting the scene for group-work had helped. They valued the opportunity to contribute to a set of guidelines as to how the team would work together, as well as engage in social activities and ice-breakers. This is supported by existing literature that highlights the importance of cultivating trust between students when establishing collaborative online learning environments[54,55]. Positive, supportive communication between the individual team members also proved important, and the participants valued a team climate that was non-judgmental, and mediated through respectful communication, despite extended periods of giving and receiving feedback within the group. The team were able to offer each other tangible, problem-solving support. The central role of such peer support in establishing psychological safety has been highlighted in the literature[52]. Also of note was an apparent timeline with regards to the establishment of psychological safety. This did not happen immediately; participants felt that it took time before they felt safe enough to share opinions and ask questions. Although there is limited research around this dimension of psychological safety, authors suggest that it likely "takes time to build, through familiarity and positive responses to displays of vulnerability and other interpersonally risky actions"[22(p.38)].

Our findings also suggest factors that can hinder the facilitation of psychological safety in online design-thinking learning environments. For example, some participants considered that the lack of face-to-face activities meant that there were less opportunities for *ad hoc* social interactions, which may have led to the development of deeper relationships. They missed spontaneous one-to-one conversations during the main sessions, and the ability to "grab a coffee" afterwards. This suggests that attention should be paid to relationship building in the design and implementation of online design thinking (e.g., through providing students with opportunities to engage in "unscripted", informal meet-ups outside of the formal schedule), a consideration that is supported by the wider learning environments literature[56,57].

Finally, we also recognise a series of outcomes that arise from the establishment of psychological safety in the online design-thinking setting. Our team reported that they felt

better equipped to collaborate with each other, engage in creative processes, and build approaches to managing uncertainty. Ultimately, team members were able to broach the risks mentioned above and share ideas and engage in feedback behaviour. This meant that they could suggest and make changes with relative ease. Again, these findings align well with the existing literature that highlights links between psychological safety and team outcomes such as innovation, creativity, performance and learning[50].

During the intervention, the students also learned about uncertainty. This was not unexpected since the overall aim of the project was to design, build and test a digital educational escape room that facilitated learning around uncertainty. However, there were a surprising number of comments that related to the design-thinking process rather than the escape room itself. Participants reported that they had become "comfortable with discomfort", and could move forward despite being faced with ambiguous or complex information. It is likely that such growth came through analysing multi-layered, complex information and engaging with multiple aspects of game design, where no clear "black or white" solution existed. The literature supports the idea that design-thinking education provides a natural environment for experiences of uncertainty. Through engaging with the process, students meet a "seemingly never-ending sources of ambiguity resulting from the indeterminacy of the design process and the equivocality it evokes"[58(p.788)]. Thus, design thinking provides a valuable opportunity for students to develop constructive approaches to working with uncertainty[59]. Although our overall project set out to create a learning resource that helps medical students to engage with uncertainty, it is likely that the process itself – design thinking within the context of a psychologically safe team climate – enabled our students to reach that goal in a different way. Our findings support the idea that "helping students to think like designers may better prepare them to deal with difficult situations and to solve complex problems in school, in their careers, and in life in general"[60(p.343)].

STRENGTHS AND LIMITATIONS

Our study offers an opportunity for educators to deepen their understanding of the role of psychological safety in online design-thinking learning environments. Our findings provide insight as to how psychological safety arises in such settings, including those factors that help or hinder its establishment. There are, however, limitations to the study. As a pilot study with a purposive sampling method, this meant our cohort was small and included students from a single discipline, medical education. In addition, our students had gone through a competitive process to gain a place on the design team and, hence, were likely highly engaged with the project and its goals. This creates a unique study context, and our findings should be interpreted accordingly. Future work that examines psychological safety in different online design-thinking settings (e.g., studies that specifically explore the experiences of multi-cultural design teams that include students) would be highly valued. We also support Edmondson and Lei's[22] call for greater research into how psychological

safety evolves in teams over time.

CONCLUSION

The aim of this study was to make an initial exploration of the role of psychological safety in an online design-thinking learning environment. Our findings suggest that psychological safety can be established in online design teams, and is a valuable construct that supports students to overcome the multiple risks they perceive when engaging in creative, online team-based work. There are multiple facilitators of establishing psychological safety in such settings including a collaborative environment, encouraging leadership, and an attention to team formation. There are also several barriers (e.g., difficulties connecting, fear of speaking, and cultural considerations). Our findings also suggest that psychological safety can help online design teams to establish creativity, collaboration, and build approaches to working with uncertainty. Finally, this study offers guidance to educators who wish to design and implement online design-thinking learning environments, and support design teams that include higher education students.

DECLARATIONS

Availability of data and material

The datasets analysed during the current study are available from the corresponding author on reasonable request.

Funding

This project was supported by the Irish Medical Council/INHED Research in Medical Education Awards, and the RCSI StEP (Student Engagement and Partnership) Initiative.

Acknowledgements

We would like to express our sincere gratitude our RSCI student and design team colleagues for their support during this research study.

Reflective statement

All members of the research team have expertise across health professions' education. JM is a faculty developer with a research interest in online learning, teamwork and management of uncertainty in health professions' education. RL is a final-year medical student with expertise in teamwork and psychological safety. JI is a health professions' researcher with expertise in qualitative methodologies. MACF is a health professions' education researcher with expertise in qualitative methods, faculty development, and critical pedagogy. HB is a researcher in health professions' education with expertise in assessment, feedback and workplace learning.

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Exploring medical students' learning around uncertainty management using a digital educational escape room: a design-based research approach

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Published in: Perspectives on Medical Education, 12(1): 86–98.

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ABSTRACT

Medical professionals meet many transitions during their careers, and must learn to adjust rapidly to unfamiliar workplaces and teams. This study investigated the use of a digital educational escape room (DEER) in facilitating medical students' learning around managing uncertainty in transitioning from classroom to clinical placement.

We used design-based research to explore the design, build, and test of a DEER, as well as gain insight into how these novel learning environments work, using Community of Inquiry (CoI) as a guiding conceptual framework. This study represented a mixed methods pilot test of a prototype DEER. Twenty-two medical students agreed to participate, and data were collected through qualitative (i.e., focus groups, game-play observations) and quantitative (i.e., questionnaires) methods.

Eighty-two per cent of participants agreed or strongly agreed that the DEER supported their learning around uncertainty. Participants offered diverse examples of how the game had facilitated new insights on, and approaches to, uncertainty. With respect to the learning environment, multiple indicators and examples of the three domains of CoI – cognitive, teaching and social presence – were observed.

Our findings suggested that DEERs offer a valuable online learning environment for students to engage with complex and emotion-provoking challenges, such as those experienced at transitions. The study also suggested that CoI can be applied to the design, implementation, and evaluation of DEER learning environments, and we have proposed a set of design principles that may offer guidance here.

INTRODUCTION

Medical professionals meet many transitions during their careers, and must learn to adjust rapidly to unfamiliar workplaces and new teams. Such profound changes begin in medical school; an early and important example of this is the transition from pre-clinical to clinical training. This step into 'real-world' medicine represents an exciting and rewarding time for medical students[1]. However, it is also a step into the unknown, with the potential to evoke experiences of stress and uncertainty[2,3]. Although many supports exist which address the knowledge and practical skills needed for clinical placements (e.g., special-purpose courses, clinical skills training), these can fall short in preparing students for 'the dynamics of a new environment, which itself is unstable'[3(p.566)]. With healthcare practice becoming increasingly complex and unpredictable[4], it is important to better prepare students to engage with dynamic clinical learning environments.

In recent years, there has been an increased interest in how medical professionals manage uncertainty, both at transitions and more generally[5] [5]. The evidence highlights that health professionals' responses to uncertainty can influence their decision-making skills[6], attitudes to patients[7], career choices[8], and experiences of work-related stress[9,10] . More recent research also suggests that it may be possible to train medical students to prepare for uncertainty[11]. Clinical debriefs, simulations, and peer-to-peer conversations have been proposed as pedagogical approaches that may help students to better manage the uncertainty of clinical practice[12,13]; however, there is little empirical research in this domain.

This study explores the use of a type of simulation-based educational game known as an escape room to facilitate medical students' learning around uncertainty experienced at the transition from classroom into clinical settings. Escape rooms are 'live-action team-based game where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal… in a limited amount of time'[14]. Educational escape rooms have rapidly become popular within health professions' education[15]. A variety of studies have explored the capacity of escape rooms to facilitate learning in clinical[16-20] and professional skills[21-23] domains. Research, however, is at an early stage with relatively little known about how learning takes place within these novel environments[24].

Escape rooms can be held within face-to-face or virtual learning environments where, in the latter case, they are referred to as digital educational escape rooms (DEERs). In this study, we built a DEER in order to explore how this learning environment might be used to facilitate medical students' learning around uncertainty, as well as to gain more general insight as to how escape rooms work. We selected the Community of Inquiry (CoI) model[25] as a guiding conceptual framework, and a lens with which to investigate the DEER learning environment. CoI is a widely studied online learning model[26,27], that can help researchers to

conceptualise 'the educational transaction and processes of learning' in online settings[28(p.9)]. The framework (Table 1) proposes that meaningful online learning arises through the development of three overlapping domains[29]:

- Cognitive presence (i.e., the extent to which learners are able to construct meaning through sustained reflection and discourse[25];
- Teaching presence (i.e., the 'design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile learning outcomes'[30(p.1)]; and,
- Social presence (i.e., 'the ability of learners to project themselves socially and affectively into a community of inquiry'[31(p.4)] .

Table 1: Community of inquiry elements, categories and indicators (adapted from Garrison & Arbaugh[32])

Elements	Categories	Indicators
Cognitive	Triggering event Exploration Integration Resolution	Having a sense of puzzlement Exchanging information Connecting ideas Applying new ideas
Teaching	Design and organisation Facilitation of discourse Direct instruction	Setting curriculum and methods Sharing personal meaning Focusing discussion
Social	Open communication Group cohesion Affective expression	Enabling risk-free communication Encouraging collaboration Expressing emotions, camaraderie

CoI adopts a collaborative-constructivist stance[33], making it a framework of particular interest for the team-based DEER learning environment[34,35] . However, there is limited empirical research here too. Thus, our research questions for this study were:

- What are medical students' perspectives on the use of a digital educational escape room to facilitate learning around managing uncertainty at the transition from classroom to clinical placement?
- What impact, if any, does a DEER have on medical students' uncertainty tolerance?
- Does CoI facilitate our understanding of DEER learning environments, and, if so, what indicators of social presence, teaching presence and cognitive presence exist?

To explore these research questions, we used a design-based research (DBR) approach. DBR is 'a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings'[36]. A key tenet of DBR is that it holds dual

goals: the research should facilitate the development of a specific innovation or intervention, whilst also testing and refining theories to gain insight into complex learning environments[37]. Although there is great variety in how DBR is implemented, this approach typically involves four stages: analysis of the problem, design of solutions, testing and iteration, and reflection[38]. In this study, we used DBR to design, build and test our DEER in an online setting whilst simultaneously furthering our understanding of the applications of CoI in this context.

METHODS

STUDY DESIGN

DBR involves the development and evaluation of multiple prototypes. An initial prototype DEER underwent evaluation[39] and data from that design cycle was used to inform the build for this second prototype (Figure 1). The current study explores a design cycle where the second prototype escape room was pilot-tested using a convergent parallel mixed methods study design[40]. We used qualitative (i.e., focus groups, game-play observations) and quantitative (i.e., questionnaires) data collection methods, with an emphasis on the qualitative strand[41]. Ethical approval for the study was granted by the RCSI Research and Ethics Committee, RCSI University of Medicine and Health Sciences (ID 202103004).

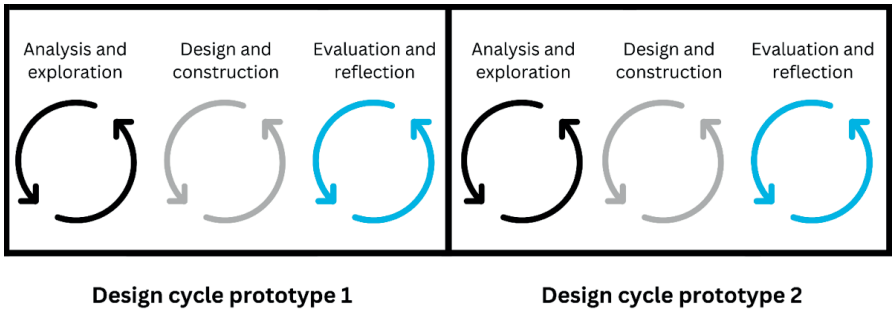

Figure 1: Data from a preliminary design cycle were used to inform the build for a second prototype

CONTEXT

The study took place at RCSI University of Medicine and Health Sciences, a culturally diverse institution with over 4,000 students from 90 different countries. The university offers a direct-entry medical programme with two pre-clinical (Years 1-2) and three clinical years (Years 3-5). Our study population consisted of students enrolled in Year 2 of the programme in advance of their commencing clinical placements. All students within this cohort were

eligible to participate, and recruitment was promoted via university email and social media. An incentive to take part, entry into a draw for a book voucher, was offered.

Study participants were invited to play a prototype DEER in October 2021. This prototype had been build using draft principles derived from the first design cycle and a review of the CoI research literature (Table 2). The DEER was designed to be played by small groups (4-5) of students, and it was intended that students would work together to overcome ambiguity, solve puzzles and 'escape' a fictional creepy hospital[39]. The DEER consisted of ten puzzles, including numerical, word-based, logic, and general knowledge formats, and three in-game reflections, which were built on an interactive content authoring platform (Genially; Madrid, Spain). Individual puzzles were designed to align with sources of uncertainty in healthcare that have been identified by Han *et al.*[43]. This meant that participants met puzzles which involved managing complex information, recognising ambiguity, and working with the different outcomes that can emerge in medicine (i.e., patient gets better, or patient does not). Although participants could follow different pathways within the DEER, all groups needed to complete a final, culminating "meta-puzzle" to complete the game.

Table 2: Design principles for DEERs that are underpinned by Community of Inquiry (CoI)

CoI presence	Design principles	References
Cognitive	• Use an engaging storyline that evokes curiosity for learners • Align escape room puzzles with educational learning outcomes • Provide challenging puzzles that provoke shared reflection	44, 45, 46
Teaching	• Provide clear instructions to learners before game • Use facilitation skills to establish a safe, supportive learning environment • Offer scaffolded support to learners throughout (e.g., pre-brief, hint strategy, technical support, de-brief)	44, 47, 48, 49
Social	• Use web-conferencing software with breakout room capability to facilitate small group interactions • Employ collaborative rather than competitive game strategies (e.g., escape against clock rather than 'first team to escape wins') • Use puzzles to evoke emotions such as confusion and excitement	44, 50, 51, 52

Prior to game-play, participants were given details of the DEER, a participant information sheet and a consent form (Figure 2). On the day of game-play, participants joined the session via Microsoft Teams (Redmond, WA, USA). There was a short introduction, or pre-brief, before participants were asked to join breakout rooms and begin the activity. The pre-brief aimed to establish psychological safety by providing clear instructions for game play, as well emphasising the fun element and the availability of help for overcoming "roadblocks" encountered during the game[47]. Each group was allocated 50 minutes of game play, and participants were directed to play as a team, appointing leaders to 'share screens' and input answers. After the allocated time, breakout rooms were closed, and a de-brief with the full cohort of students was held. The de-brief was designed to allow

participants an opportunity to disclose and discuss the uncertainties that arose for them, as well as other experiences that they felt were important. The de-brief also offered a space for the participants to engage in shared reflection around the key learning outcomes from game play, including the in-game reflections. Finally, an email with uncertainty management resources and a link to the DEER was sent to participants after the session.

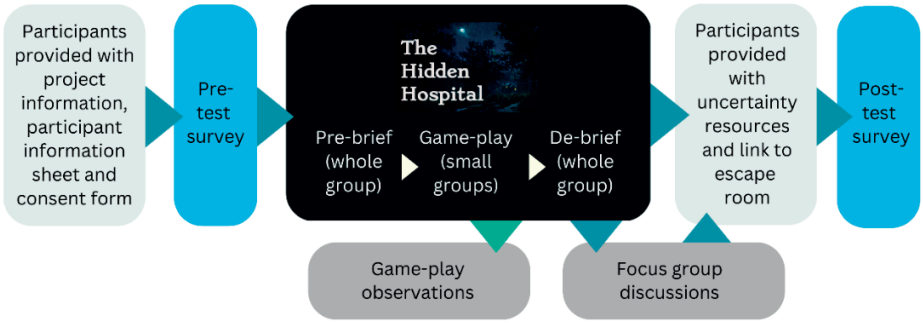

Figure 2: Flow chart of the study design

DATA COLLECTION

Qualitative data collection

Qualitative data were collected during game-play and immediately afterwards through focus group discussions. Game-play and break-out rooms were video-recorded and the audio component transcribed. Text from the session web-chat as well as observational data (e.g., the actions of the participants) were also recorded. The focus group discussions, facilitated by experienced researchers using a pre-determined question guide, were also video-recorded and the audio transcribed. Focus group participants were also invited to submit text responses via a digital noticeboard, Padlet, to ensure everyone had the opportunity to provide feedback (Padlet; San Francisco, CA, USA), which were collected.

Quantitative data collection

Quantitative data were collected before and after the game-play session through use of pre- and post-intervention questionnaires, via an online survey platform (SurveyMonkey; San Mateo, CA, USA). Data collection was intended to capture any impact of game-play on participants' uncertainty tolerance. The pre-intervention questionnaire consisted of: the Intolerance of Uncertainty Scale (Short Form) (IUS-12), a 12-item questionnaire which assesses individuals' perceptions of uncertainty and which has previously demonstrated high internal consistency ($\alpha = 0.91$) with medical student cohorts[53]; the Tolerance for Ambiguity (TFA) Scale, a 7-item questionnaire which assesses individuals' tolerance of general uncertainty in life and which has demonstrated acceptable internal consistency

with cohorts of medical students (α = 0.75)[54]; and, a set of demographic questions. The post-intervention questionnaire consisted of repeats of the IUS-12 and TFA, alongside a 12-item escape room perception survey adapted from Eukel *et al.*[55].

DATA ANALYSIS

Qualitative data analysis

Two separate qualitative data analyses were carried out. The first analysis explored the focus group transcriptions and digital noticeboard text. Here, data were combined and organised using NVivo 12 (QSR International; Melbourne, Australia), and examined using a reflexive thematic analysis approach[56]. The researchers used an initial inductive step to understand the experiences of the students in relation to the escape room. JM listened to the audio data, and then read and re-read the transcribed recordings. JM then created initial codes, which were specifically related to participants' perspectives of using a DEER to facilitate learning around uncertainty. JM then applied a subsequent step of deductive analysis whereby the data was examined with respect to the social, cognitive and teaching presences of CoI. Following several passes through the data, themes were identified, refined and re-organised before final agreement with the research team (JM, DC & JI).

The second analysis explored the game-play transcriptions, web-chat and qualitative observational data. Here, JM and DC used a CoI instrument adapted from McKerlich & Anderson[48] to examine the data. This involved viewing the session videos twice, reading and re-reading the session transcripts and web-chat text, before discussing and documenting indicators and examples of social, cognitive and teaching presences. The researchers drew on existing CoI research[49,51,57] to help define boundaries around the presences.

Quantitative data analysis

Quantitative data were analysed in two stages. First, the pre- and post-intervention surveys items were analysed. Internal consistency was assessed by calculating Cronbach's coefficient alpha for each[58], and a Shapiro-Wilks test was used to assess the normality of the resulting data. A paired-design t-test was used to determine if there was a significant difference between the scores on the IUS-12 scale and the TFA scale pre- versus post-intervention. A separate test was carried out for each of the scales and alpha was set at 0.05.

Second, a one-sample t-test and descriptive statistics were used to explore responses to the escape room perception survey. The perception survey was measured on a five-point Likert scale ranging from '1 = strongly disagree' to '5 = strongly agree', with items 9 and 10 of the survey reverse-scored. The one-sample t-test assessed whether students' mean (SD) perception score was significantly different to the mean value of the scale, '3 = not agree nor disagree'. All statistical analyses were carried out using STATA statistical package version 17 (StataCorp; Texas, USA).

REFLECTION

As a final stage of data analysis, the research team (HB, MDF, JM and DC) met to discuss the data in relation to the initial DEER design principles. The researchers examined the data through the lens of the CoI framework and engaged in shared reflection, with the aim of co-constructing an updated set of design principles.

RESULTS

Our results are organised in two sections. First, we report findings that relate to our first and second research questions, i.e. exploring the use of a DEER in relation to medical students' learning around, and tolerance of, uncertainty. Second, we report findings that relate to our third research question i.e. investigating the CoI as a framework of relevance in understanding DEER learning environments. Twenty-two second year pre-clinical undergraduate medical students (10 female and 12 male students) agreed to participate in the study. Participant quotes, with details on focus group, gender and participant number (e.g., FG1F1), have been provided.

USING A DEER IN RELATION TO MEDICAL STUDENTS' LEARNING AROUND, AND TOLERANCE OF, UNCERTAINTY

Qualitative data

Ten participants (four female; six male students) participated in two focus group discussions. Data analysis of the focus groups identified two themes that related to the participants' perspectives on using a DEER to facilitate learning around uncertainty: affective experiences of uncertainty, and building approaches to uncertainty.

The participants highlighted that the DEER learning environment provided multiple opportunities for affective experiences of uncertainty. They noted that playing the game felt inherently uncertain due to the challenges of the puzzles and the ambiguous clues. Others felt unsure about what the game would entail, and whether it would represent a good use of their time. Further to this, participants reported uncertainty in relation to working with new and unfamiliar colleagues. Some participants expressed self-doubt and a sense of vulnerability in relation to their abilities (i.e., whether or not they would be able to complete the game, or contribute to the team). *'I don't know if I need tonnes of outside knowledge and all? I don't want to be the weak person, throwing out stuff that's completely left field and not at all correct.'* (FG1F1)

One group reported experiences of uncertainty due to a technology breakdown (i.e. lagging internet connection). Overall, participants spoke of uncertainty in terms of a variety of different emotional states including anxiety, frustration, curiosity and excitement. '*I've*

never actually ever come across something like this escape room... I was pretty curious and anxious, like what it is we will actually do?' (FG1M1)

The participants discussed ways in which the DEER had helped them to think differently about uncertainty. They highlighted new strategies in managing uncertainty, such as adopting a team approach (i.e., harnessing different perspectives). The validation and support of others helped them to propose ideas and solutions, despite feeling unsure. *'A lot of moments I was confused and didn't know what to do and they backed me up. Individually, we didn't know everything. This is something we all need to learn, it's an important student experience. It was like a metaphor for diagnosing patients.'* (FG1M2)

Participants also reported that the game had helped them to engage with critical thinking and creative approaches to problem solving. Others alluded to shifts from negative to more positive mind-sets around uncertainty. *'There will be times when we will be uncertain so it shouldn't be a factor that makes us feel uncomfortable. It should be a motivating factor to learn more.'* (FG1M3)

However, not all participants agreed that they had learned about uncertainty. Some felt that the puzzles did not reflect the uncertainty experienced in real-world, clinical practice. Others commented that the learning was not linked to their course work, and thus seemed less relevant to them. These views were predominant within the group who had experienced technology problems.

'I just feel like, have we really learnt anything by playing the game?' (FG2F1)

Quantitative data

Sixteen participants (16/22, 73% of the study cohort) completed both the pre-intervention and post-intervention questionnaires. The reliability was high for the IUS-12 scale (Cronbach's alpha = 0.89) and acceptable for the TFA-scale (Cronbach's alpha = 0.74). The data were found to be normally distributed on the Shapiro-Wilks test. No significant difference in Intolerance of Uncertainty ($t = 0$, $df = 15$, p-value = 1) nor Tolerance of Ambiguity ($t = -0.81$, $df = 15$, p-value = 0.43) was detected between the pre-intervention group and the post-intervention group.

With respect to the escape room perceptions survey, 17 participants submitted responses (77% of the study cohort) (Table 3). The mean perception value for the cohort ($m = 3.99$ +/- 0.59 sd) on a five-point evaluation scale was significantly higher than the neutral point (3) of the evaluation scale ($t = 6.98$, $df = 16$, $p < 0.01$). This suggests that the students' perceived learning through the escape room was strongly positive.

Table 3: Escape room perception survey (n=17) (adapted from Eukel *et al.*[55])

Item	Mean (SD)	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
1. The escape room encouraged me to think about material in a new way	3.7 (0.3)	5.9	5.9	23.5	41.2	23.5
2. I would recommend this activity to other students	4.5 (0.2)	0	5.9	0	35.3	58.8
3. I learned from my peers during the uncertainty escape room	4.3 (0.1)	0	0	5.9	58.8	35.3
4. The escape room was an effective way to review the topic of uncertainty	3.6 (0.3)	11.8	11.8	0	58.8	17.6
5. The escape room was an effective way to learn new information related to uncertainty	3.5 (0.3)	5.9	17.6	11.8	52.9	11.8
6. I learn better in a game format than in a lecture	4.6 (0.1)	0	0	0	41.2	58.8
7. The escape room was an effective way to assist my learning around managing uncertainty	3.7 (0.3)	5.9	11.8	5.9	58.8	17.6
8. I feel I was able to engage with my teammates to learn new material	4.0 (0.2)	0	5.9	5.9	70.6	17.6
9. It was difficult for me to focus on learning because I was feeling stressed or overwhelmed	3.9 (0.2)*	29.4	41.2	17.6	11.8	0
10. The non-educational portions (e.g., puzzles, etc.) distracted me from learning about uncertainty	3.4 (0.3)*	11.8	47.0	17.6	11.8	11.8
11. I prefer assembling information from a variety of sources when learning new material	4.1 (0.2)	0	5.9	11.8	47.0	35.3
12. In general, I enjoy playing games (video games, board games, social media games, etc.)	4.8 (0.1)	0	0	0	23.5	76.5

* n.b. Items 9 and 10 were negatively worded have been reversed-scored during analysis

The majority of participants (n=14, 82%) agreed or strongly agreed that the escape room was an effective way to assist their learning around managing uncertainty. Ninety-four per cent of the participants agreed or strongly agreed that they had learned from their peers during the game-play session. Finally, 94% of participants agreed or strongly agreed that they would recommend the game to other students.

COI AS A FRAMEWORK OF RELEVANCE IN UNDERSTANDING DEER LEARNING ENVIRONMENTS

Data collected during the focus group discussions and the game-play sessions were categorised according to the presences of CoI: cognitive, teaching and social[25].

Focus group data

Within the focus groups, participants highlighted several aspects of the escape room experience that appeared to be consistent with CoI. With respect to social presence, they reported that the game provided a warm environment that supported team interaction. They felt validated, supported and motivated by each other during game play, and reported a wide range of affective experiences including: curiosity, enjoyment, excitement, fun, pride, relief, satisfaction, annoyance, anxiety, confusion, exasperation, and frustration (Table 3). With respect to teaching presence, participants noted the role of the instructor in: setting the tone for the game; establishing team collaboration; offering clear instructions; providing guidance and technical help; supporting insights around uncertainty; and re-emphasising the game's learning outcomes (Table 3). One aspect of the game's design that evoked mixed opinions was the 'race against the clock' time strategy. Some participants reported that the time pressure added to the fun, and helped them to establish trust within their team quickly. Others said that time pressure caused them to rush through the game, sometimes progressing without fully understanding a topic. With respect to cognitive presence, there were relatively fewer comments. Although many participants reported that the game had involved them in cognitive effort, there appeared to be variation in how deeply they engaged with the puzzles. Many participants commented that the in-game reflective activities broke their sense of flow and immersivity within the game.

Game-play data

Qualitative data collected during game-play also highlighted multiple indicators and examples of cognitive, teaching and social presence within the DEER (Table 3). With respect to cognitive presence, participants seemed to share information, connect ideas and test theories with each other. Cognitive presence appeared to be most salient during puzzle-solving interactions. Teaching presence was observed in the planning and organisation of the DEER as well as through facilitation of discourse and direct instruction, which could be subdivided into facilitator and peer categories. Teaching presence related to the facilitator was dominant in the pre- and de-brief sections, whereas teaching presence related to the

participants was dominant within the breakout rooms. Social presence was observed during all stages of the session with multiple examples of open communication, group cohesion and affective expression. With regards to the latter, many overt expressions of uncertainty were observed within the peer interactions.

REFLECTION

Following analysis of the data and a process of shared reflection, the research team co-constructed a list of revised design principles for DEERs that are underpinned by the CoI framework (Table 4).

Table 4: Revised design principles for DEERs that are underpinned by Community of Inquiry (CoI)

CoI presence	Design principles
Cognitive	• Use an engaging storyline that evokes curiosity for learners • Explicitly align escape room puzzles with meaningful/purposeful learning outcomes • Provide challenging puzzles aligned with learners' developmental levels which provoke shared reflection
Teaching	• Open the game with a pre-brief which provides clear instructions, encourages engagement and establishes a safe, supportive and playful learning environment • During the game, maintain learner engagement through responsive facilitation (e.g., technical support), and effective game design (e.g., hint strategy) • After the game, use a debrief to help learners to make sense of the activity, facilitating the resolution phase of cognitive presence as well as emotional closure for learners • Encourage engagement and peer-learning through consideration of small group size and composition, and team-work strategy • Assist learners who are not familiar with each other to build rapport (e.g., through introductions and ice-breakers) • Ensure that game play and the 'rules of engagement' align with the intended cognitive process, learners' behaviour, and learning outcomes
Social	• Use web-conferencing software with breakout room capability to facilitate small group interactions • Employ complementary game strategies, from social collaboration to healthy competition, optimising learners' engagement • Use puzzles to evoke emotions that increase arousal and positively impact on cognitive presence

DISCUSSION

This study sought to explore medical students' perspectives on the use of a DEER to facilitate learning around managing uncertainty at the transitions from classroom to clinical placement, and what impact, if any, a DEER has on students' uncertainty tolerance. Our findings suggest that DEERs generate an engaging online learning environment that allows medical students to meet with uncertainty in a safe and constructive manner. Many of these uncertainties appear to resonate with those experienced by medical students at clinical transitions (i.e., making sense of ambiguous information, engaging in decision-making under time pressure, and building trust quickly with unfamiliar people). Although at least some of the uncertainty

was evoked through the novelty of the DEER, which may decrease as students become more acquainted with such strategies, the game seemed to provoke relevant affective states and offer a supportive environment that facilitated shared disclosure.

Our findings also suggest that the DEER had facilitated learning around uncertainty management. The majority of students perceived that the DEER had assisted their learning, whilst the focus group discussions revealed examples of students' insights and approaches to managing uncertainty. For example, students reported that they held a better understanding of the different strengths and perspectives a team can bring to meet a challenging situation, again a finding that translates well into the clinical setting. However, not all students enjoyed, or perceived that they had learned from, the DEER. For example, students that had encountered technology problems during game-play were less positive about the experience overall. This highlights that issues such as internet access and digital skills represent an important challenge for DEERs in comparison to physical escape rooms. Furthermore, quantitative data analysis found no evidence that the DEER had had an impact on the students' uncertainty tolerance. It may be that a once-off intervention or a short interval between measurements was insufficient to detect a change in students' responses. The small cohort of this pilot study makes it difficult to draw firm conclusions.

We also set out to explore whether or not the CoI framework could facilitate our understanding of DEER learning environments, and, if so, what indicators of social presence, teaching presence and cognitive presence exist. Our findings strongly suggest that CoI has a natural resonance with DEER learning environments, and that the framework can shed light on how learning takes place in such novel online settings. We also found evidence of cognitive, teaching and social presences that we will discuss in relation to the existing literature below.

Social presence, which relates to open communication, emotional expression, and group cohesion[51], was widely evident within the participants' interactions. The DEER seemed to encourage rapid rapport and trust building, and despite some initial hesitation about playing the game with unfamiliar individuals, they quickly settled into teamwork. This was particularly apparent in the breakout rooms where, in the absence of the instructor, participants engaged in supportive, informal and humour-filled verbal communication. This finding supports previous CoI research[59(p.6)], which suggests that 'synchronous communications can be especially useful in quickly establishing, building and modelling social presence.' There were also many, varied expressions of affective experiences during game play. Aside from uncertainty, students reported feeling enjoyment, humour, curiosity and pride, as well as anxiety and frustration. These findings support evidence that DEERs can offer learners opportunities 'to deal with and overcome intense negative emotions, in particular fear or disgust, to move forward'[60(p.16)], which may be particularly useful in preparing medical students for 'emotion-laden' clinical experiences[61(p.198)].

Teaching presence was also evident within the escape room environment, with different aspects apparent at different stages of the game. For example, teaching presence centred on the instructor during preparation for the game and within the pre- and de-brief sections. Teaching presence centred on peer interaction was most apparent in the small-group breakout rooms. This finding underlines a view within CoI research that 'the term for this component of the CoI is 'teaching' and not 'teacher' presence. This provides room for, and encourages, students to take a positive and visible role in the learning of their peers'[59(p.7)], The extension of teaching presence to embrace students as teachers has been proposed as a 'vital question' which should be addressed as the CoI model matures[62(p.27)]. Our findings suggest that DEERs can provide a valuable learning environment for peer learning which may help student to understand the salience of 'building relationships with staff, peers or near-peers' in clinical settings[3(p.566)]. 'Students as teachers' also hints at a potential for DEER activities be scaled up, offering an effective vehicle for active learning in online, large group classrooms. To do so, it may be helpful for educational game designers to consider including opportunities for students to take on instructional roles when planning game-play strategies.

Indicators and examples of cognitive presence were also apparent within the DEER, although fewer in number. This is not surprising considering that cognitive presence, which represents a critical-thinking process that switches 'between the public shared world and the private reflective world'[25(p.21)], can be hard to observe. Here, it appeared that the emotional arousal elicited by the puzzles drew most students into a cycle of cognitive activity. At times this activity seemed aligned with the deep processes involved in cognitive presence but, at others, it seemed more superficial. It is worth highlighting that lively interaction may be present in a learning environment, but if it does not support participants to integrate ideas into meaningful constructs, it does not represent the existence of cognitive presence[63]. This finding may be due to the design of this specific DEER, i.e. here the aim was to provoke experiences of, and reflections on, uncertainty, rather than present content material that provoked deeper cognitive processing. Nonetheless, our results suggest that strong alignment of game-play and puzzle content with learning outcomes is advisable.

Other elements of the game design also seemed to impact on cognitive presence. For example, the in-game reflective activities encouraged some students to engage in shared reflection, whilst triggering annoyance and frustration for others. Furthermore, the game's time strategy seemed to impact on the students' approaches to puzzles in different ways. Some groups found the time limit exciting, whilst others experienced it as pressure, causing them to skip over the activities. This tension between achieving game goals and engaging in deep, reflective learning in a time-constrained game environment has been highlighted in the literature[64,65]. Thus, whilst our findings suggest that DEERs offer advantages in keeping learners 'on-task' in the online setting, care must be taken to ensure that puzzles and game-play align with intended learner behaviour and meaningful learning outcomes, which award

students with a 'sense of purpose'. For example, a limited-time strategy that encourages students to 'race to the finish' might be useful for exploring a clinical scenario where quick action is required (e.g., managing sepsis); however, the sense of urgency this evokes may divert students away from the sustained communication required for cognitive presence[65].

LIMITATIONS AND FUTURE RESEARCH

Our study population represented a small convenience sample of medical students. It is likely that our participants were inherently interested in educational escape games, and a larger cohort of participants may have led to different findings. A larger sample size would also be helpful in identifying any statistically significant changes between the pre- and post-intervention questionnaire responses. To deepen our understanding of how the CoI framework can be used in the design and implementation of DEERs, we recommend that further research is carried out in different contexts, with different DEER formats and diverse populations of students. A future prototype of this DEER will be incorporated into the medical programme at RCSI University of Medicine and Health Sciences in 2024, providing an opportunity to test our proposed design principles, and to evaluate the scalability of the intervention in a large group classroom. More broadly, this study highlights the opportunities provided by DBR in supporting the development of educational resources, alongside gaining insight as to how these operate within specific learning environments. DBR may be of specific interest to health professions' educators who wish to investigate the application of innovations such as virtual reality, augmented reality and artificial intelligence within real-world settings.

CONCLUSION

Overall, our study suggests that DEERs offer a suitable learning environment for medical students to engage with complex, team-based and emotion-provoking challenges, such as those experienced in the transition from pre-clinical to clinical training. Our findings also support the value of CoI as a lens through which the DEER learning environment can be explored. The framework has highlighted important considerations in the advancement of this specific prototype, as well as offering more general guidance with respect to the cultivation of engaging, collaborative DEER learning environments. We concur with McKerlich and Anderson's[48(p.48)] assertion that CoI offers a valuable way to 'describe and assess educational experiences and contexts'. As research around game-based learning and simulation games expands, these approaches are likely to gain ground on more traditional pedagogical methods in health professions' education.

ACKNOWLEDGEMENTS

The authors would like to offer their sincere gratitude to Prof. Richard Arnett, Dr Caitriona

Cahir, Ms Yeukai Chikwamba, Mr Mark Ennis, Dr Heidi Eukel, Dr Michelle Flood, Ms Sarah Flynn, Prof. Randy Garrison, Dr Emma Grigg, Mr Ray Lohan, Dr Gozie Offiah, Ms Mary Smyth, Ms Joanna Zawadzka, and the medical students of RCSI for their support in this project. Thank you also to Drs. Norman Vaughan and David Sklar who inspected draft versions of this article.

FUNDING

This project was supported by funding from the Irish Medical Council/INHED Research in Medical Education (RIME) Award, and from the RCSI StEP (Student Engagement and Partnership) Framework.

COMPETING INTERESTS

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Building digital escape rooms for learning: from theory to practice

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Published in: The Clinical Teacher, 20(2), e13559.

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ABSTRACT

Digital games are increasingly used to support learning across a diverse range of cognitive, affective, and psychomotor domains in health professions education. Game-based learning will likely become an important competency for educators. However, educators can perceive game building as out of their reach due to a lack of expertise in digital technology. This toolbox offers advice to health professions educators who would like to build a simple game for learning known as a digital educational escape room.

LESSONS LEARNED

- Designing games for learning involves decision making around pedagogy, game elements, and technology
- Game building should follow a structured process, involving early and frequent testing with game users
- Digital educational escape rooms (DEERs) are increasingly used in health professions education to facilitate learning

INTRODUCTION

Online or digital games are rapidly emerging within health professions education. This phenomenon is in part due to the "rising tide" effect of a global gaming industry that is growing dramatically, and projected to reach a value of $321 billion by 2026[1]. At the same time, studies highlight the capacity of digital games to motivate and engage learners, and facilitate learning across a wide range of cognitive, affective, and psychomotor domains[2]. An appetite for games also stems from students' increasingly high expectations for quality and variety in online learning environments[3].

It is likely that game-based learning will become an important competency for educators. However, there are perceived barriers. Educational games have a reputation for being costly and time-consuming to produce[4], and educators can perceive that they lack the technology skills to build effective games[5]. A potential solution may be the wide range of low-cost, game-building resources that have become available in recent years. These technologies allow educators without programming skills to create games that they can tailor to their own teaching context.

In this toolbox, the authors draw on the game-based learning literature, as well experience of building several digital games, to offer guidance to educators who would like to build their first game for learning. Here, we describe the use of an online content-authoring tool to build a simple digital educational escape room. An escape room is defined as a "live-action team-based game where players discover clues, solve puzzles, and accomplish tasks in one or more rooms to accomplish a specific goal... in a limited amount of time"[6(p.1)]. When such games are used to support learning in virtual or online settings, they are often referred to as digital educational escape rooms (DEERs). DEERs can be created relatively easily on low budgets, and have wide applications in health professions education[7-9], making them an excellent "starter" game for novice game-builders.

BUILDING YOUR GAME

In building a game for learning, it's important to reflect on what you want to accomplish and how a game will facilitate this. Consider what you want the game to do: Is there an aspect of your teaching that you would like to improve? Is there a concept that students continually find hard to grasp? What aspects of a game environment would you like to harness? For example, the authors used a DEER to create a learning environment which would evoke feelings of uncertainty for the players, and provide a facilitated space for shared reflection around uncertainty and its management.

Clarity on your aims also helps you to decide who will be on your design team. Although it's possible to create a DEER on your own, team-led designs usually lead to more robust games. Design teams offer a valuable opportunity for inter-professional and educator-student collaboration, with students – the game users – bringing particular insight into how a game might work in practice[10].

Game design is a creative, dynamic and non-linear process, so it's important to adopt a structured approach. We used a design-thinking approach, whereby we aimed to develop a deep understanding of the end-user that informed the creation of a prototype game that could be tested and iterated. Design thinking follows five phases: empathise, define, ideate, prototype, and test[11]. In building a game, you can adapt each phase to the specific requirements of your project. For example, games can be developed over a few days or across several weeks, depending on your timeline (Table 1 shows a sample design-thinking schedule for building a DEER). This approach provides the design team with a structure in building the "nuts and bolts" of their educational game, and making key decisions in relation to pedagogy, game elements and technology.

Table 1: Sample design-thinking schedule for building a DEER

Week	Theme for week	Tasks for the week
1	Getting started	• Design team is established • Opening conversations held around DEER aims and how it will meet the needs of users (i.e. the opening "design challenge") • Team members play online escape rooms together as ice-breaker and for game design inspiration
2	Discovery and empathy	• Team members explore the issues which will be addressed by the DEER by meeting with experts and reviewing current literature • Design team engages in field work to explore the needs of potential game users e.g. by talking to students or other educators (also known as "empathy interviews")
3	Definition and Interpretation	• Design team discusses and organises their findings so far, identifying key issues for the DEER to address (i.e., "affinity mapping") • Team members begin thinking about potential themes and narratives for the room as an individual process
4	Ideation #1	• Design team shares ideas for themes and narratives and discusses merits of each • Design team is broken into small groups to begin creating simple puzzles
5	Ideation #2	• Team members share and play-test each other's puzzles • Team members use a storyboarding exercise to compare different DEER themes and narratives and select a favourite
6	Building our prototype	• Puzzles are refined according to play-test feedback and then added to the Genially platform • Team members decide on the "flow" of puzzles (i.e., the sequence in which they will be played)
7	Play-testing and refining	• An initial prototype of the game is play-tested by the design team and "critical friends" (i.e., colleagues, friends and family) • The team discuss feedback from the game play and refine the prototype accordingly
8	Evaluation and further refining	• A further prototype of the game is evaluated with groups of end-users

PEDAGOGY

As with any teaching innovation, DEERs must be underpinned by solid pedagogical principles. A key anchor point for your game, is its specific learning outcomes: what will the students know or be able to do as a result of playing? Will your game focus on *what* students learn (e.g., core content), or on *how* they learn it (e.g., communication and problem-solving)? Students are more likely to value games that closely support their coursework, so ensure that the DEER learning outcomes align with the curriculum. Also, consider what learning theory you will use to connect game play to learning. A wide range of theories (e.g., adult learning and experiential learning) can be applied to escape games[12]. We used Community of Inquiry, a collaborative-constructivist theory of online learning, to inform our game's design[13]. This theory highlights the importance of discourse in facilitating online learning, thus guiding us to build a prototype game that used online breakout-rooms to facilitate small group discussions. In addition, the theory helped us to see the value of adding a post-game de-brief to consolidate learning.

GAME ELEMENTS

Well-designed DEERs are both educational, and enjoyable to play. Game design invites us to create an immersive learning environment for the player through creating emotive themes and narratives. Whilst the theme is the overall 'look and feel' of the escape room (e.g., an alien landscape or a viral outbreak), the narrative is a more defined description of the storyline and characters. Devising these elements is a fun and highly creative process, and design thinking invites us to "go wild" with imagination. Our design team built a narrative by first coming up with ideas individually, before sharing these and then voting for a favourite. The chosen narrative was further developed by the team. In practical terms, we "storyboarded", or sketched out, the ideas (Figure 1).

Design teams must also create puzzles, another core game element for DEERs. At its most basic structural level, a DEER consists of several puzzles, with players using clues (keys), to solve puzzles (locks), to "escape" the game. In the online setting, puzzles tend to include codes, crosswords, riddles, and maths or pattern-based puzzles (Figure 2).

Design teams can develop their own "home-made" puzzles, or use one of the many freely available online puzzle-building websites. Creating puzzles can be tricky, and it is often difficult to know whether a puzzle works well or not. If puzzles are too easy and under-challenge your players, they may lose interest. Too difficult, and learners can become frustrated and discouraged[14]. Puzzles should be tested and iterated. In practice, our team broke out into small groups, created puzzles which they then swapped and play-tested. The small groups used a reflection template to trigger deep thought around puzzle characteristics such as difficulty level, hint strategy, as well as an educational blueprint, to ensure puzzles were aligned with the DEERs learning outcomes.

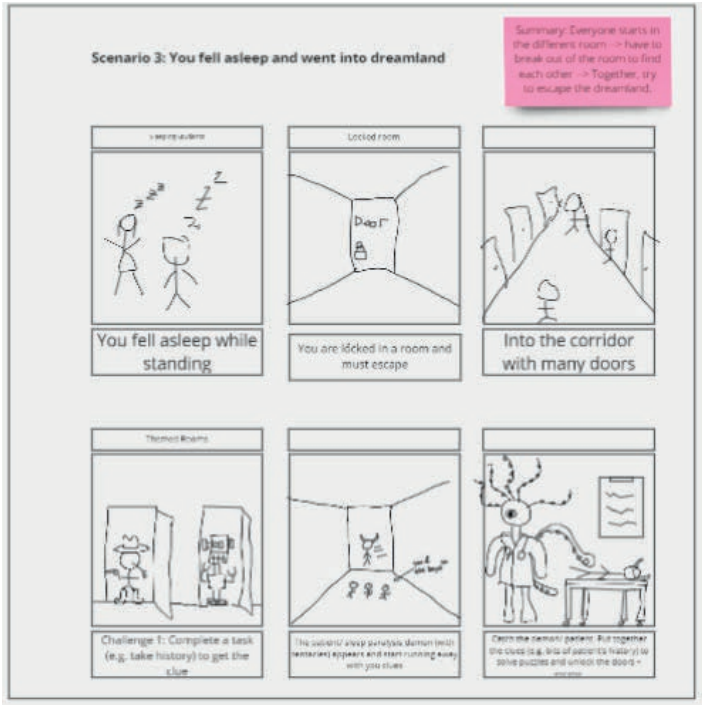

Figure 1: DEER themes can be mapped out visually or "storyboarded"

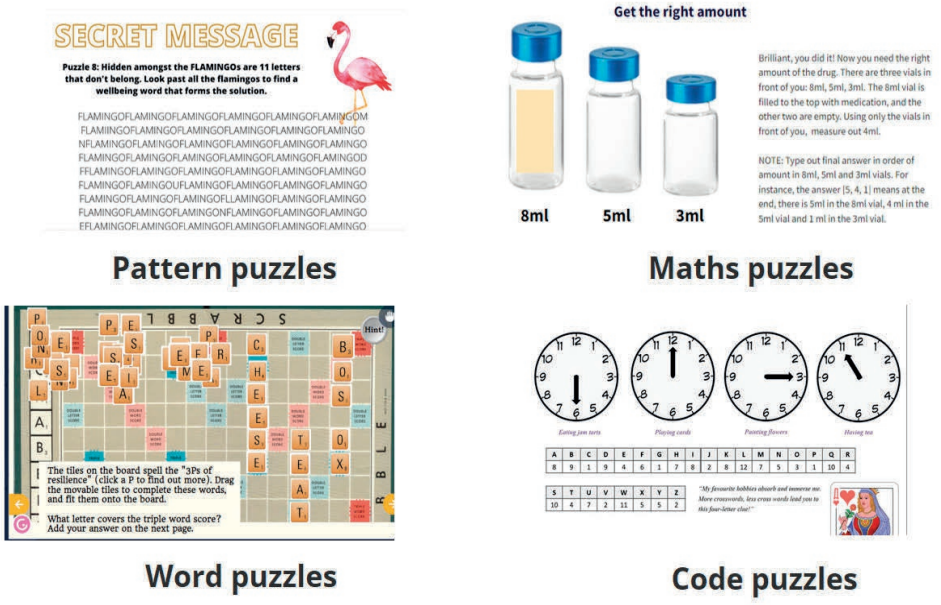

Figure 2: In the online setting, puzzles can include codes, crosswords, riddles, and maths or pattern-based puzzles

A further game element to consider is timing; the duration and pace of a game can influence the overall learning experience. For example, a game with a 30-minute limit, and a 'first team to escape wins' strategy will result in a fast-paced activity with a level of pressure and competition. For deeper, discussion-based learning, it may be helpful to add a looser time limit and avoid a competitive strategy[15].

TECHNOLOGY

There are a wide range of digital technologies which can support DEER-building. We used the content-authoring tool Genially (Madrid, Spain) which offers ready-made and customisable escape game templates. The DEER is built through creating a slide deck on the platform, with individual slides connected through hyperlinks and interactive buttons. Thus, game players can click on slide "hotspots" and follow different game pathways. Puzzles were built by creating imagery into the Genially slide deck. Here, the visuals aimed to support the DEER's theme and narrative, and create a sense of immersivity for the player (Figure 3). It's also necessary to decide on how technology can be used to bring game players together. We wanted our students to engage in real-time communication, choosing the web-conferencing software Microsoft Teams (Redmond, WA, USA) to support this.

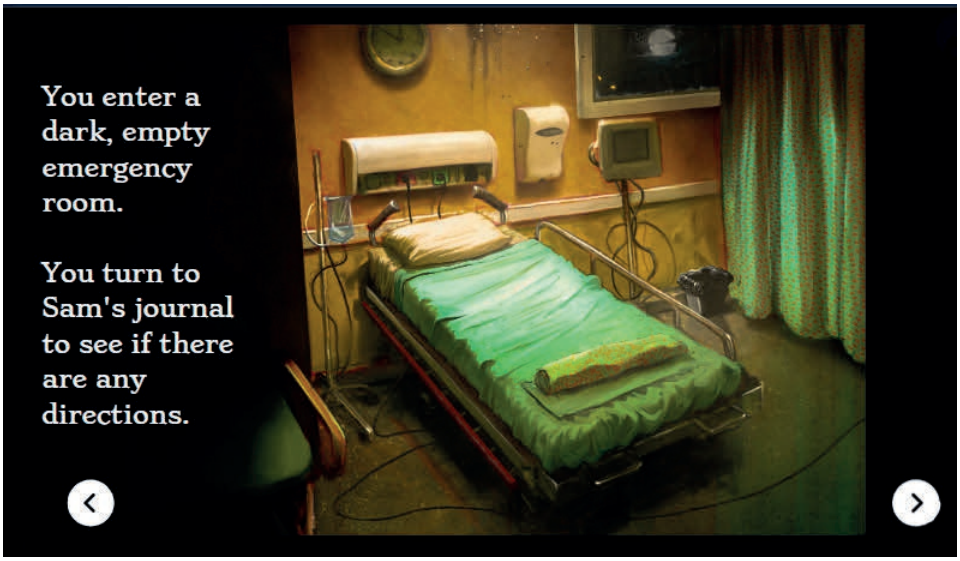

Figure 3: DEER visuals support the game's theme and narrative, and create a sense of immersivity for the player

The first iteration of your game will not be perfect and it's a good idea to test your ideas early and often. Once we had added puzzles to Genially, we tested the game within the design team to highlight any technology issues, or broken links. We also invited "critical

friends" (i.e., colleagues, friends and family) to test the game and give us feedback. After incorporating suggested changes, we play-tested a further iteration with several groups of students. The more diverse the cohort the better (e.g., aim to include play-testers who are not keen on online games as they often offer the most valuable insight). During these play-test sessions, a member of the design team can sit in as a silent observer or game-play can be recorded. Feedback from play tests can be used to refine and improve the prototype, resulting in a game which can be rolled out with your learners. Once your game is *in situ*, you can evaluate it through either qualitative (e.g., focus groups or interviews of game users) or quantitative (e.g., pre and post-game surveys) approaches[16-17]. Evaluation helps us to understand how a game facilitates learning in a real-world setting, and informs further iterations and refinements.

OPPORTUNITIES AND CHALLENGES

The design, build and evaluation of educational games can be complicated and time-consuming, with multiple stakeholders engaging in a variety of creative tasks. However, by employing a structured approach, design teams can create a lasting educational tool which can be refined and re-used with future student cohorts. There is also potential to scale up digital escape rooms for use with large class sizes. This means that DEERs offer an opportunity for educators to "frontload" their time and effort when teaching in online or blended learning settings.

CONCLUSIONS

Digital educational escape rooms are a flexible, versatile strategy that can support active, collaborative learning in the online space. They also provide a valuable opportunity for authentic, educator-student and inter-professional collaborations that can result in educational resources that are uniquely tailored to a teaching context. There are an increasing number of digital tools and technologies that can help educators and students to build online escape games without technical expertise. Finally, DEERs entail multiple design choices around pedagogy, game elements and technology, and it is recommended that game design follows a structured process, involving early and frequent testing.

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Discussion

8

The overall aim of this thesis was to investigate how health professions' students learn to manage uncertainty during their undergraduate training. We began in Chapter 2 with a review of the existing literature which revealed that experiences of uncertainty are commonplace for learners, and can influence them in many different ways, throughout their education. Despite this, there are few examples of formal teaching methods that directly address uncertainty within health professions curricula, with learning tending to take place through more informal processes. Another finding from the review was that health professions educators play a key role in assisting learners to manage and make sense of uncertain situations. This finding was explored further through a study focusing on an educational workshop, the results of which were presented in Chapter 3. This study helped us to establish the value of a recognised taxonomy of healthcare uncertainty[1] in an educational context. We carried this taxonomy into a third study and used it as a guiding framework in building a digital educational escape room (DEER) which could facilitate health professions students learning around uncertainty. Adopting a design-based research (DBR) approach allowed us to develop the DEER, whilst also expanding existing knowledge around how learning takes place in such novel online settings. In Chapter 4, we reported on an evaluation of a prototype escape room. Chapter 5 examined the online design-thinking process which was used to create the DEER, with a specific focus on psychological safety as an enabler of creative online collaboration. In Chapter 6, we investigated how learning takes place in DEER learning environments, applying Community of Inquiry (CoI)[2] as a conceptual framework of interest in their design and implementation. Finally, in Chapter 7, we harnessed our overall research findings to present practitioner recommendations for individuals who would like to develop their own digital escape games for learning.

In this chapter, we summarise the findings of these studies in relation to the proposed research questions of the thesis. We then reflect on the implications of this work for both theory and practice, distilling key messages for educators, researchers, students and other stakeholders. Finally, we also analyse the strengths and limitations of the research presented in this thesis, as well as offer recommendations for future research pathways.

SUMMARY OF FINDINGS

HOW DO UNDERGRADUATE HEALTH PROFESSIONS STUDENTS LEARN TO ENGAGE WITH UNCERTAINTY RELATED TO THEIR ACADEMIC PRACTICE?

Our research findings suggested that uncertainty is a commonplace experience for undergraduate health professions students, who met a wide range of uncertainties that related to healthcare, to the educational environment, and to their own selves. These uncertainties arose at many different stages and settings during their education, although clinical practice and transition events (e.g., starting new placements or rotations) seemed

to be particularly influential. It was also apparent that students experienced uncertainty in highly unique ways, mediated by both individual (e.g., gender, age, background, discipline, and stage of training) and systemic (e.g., organisational culture, socio-cultural) factors. Interestingly, several studies[3,4] proposed that a "culture of certainty" in healthcare may provoke learners to downplay or mask their uncertainty[5]. Others highlighted the discomfort felt by students in coping withuncertainty[6] that could, for some, contribute to psychological distress[7]. This perception of uncertainty as something unpleasant, and to be avoided or minimised, has been observed by other authors[8,9], and may indicate a reason as to why uncertainty is not more fully embraced within health professions curricula.

Our research also highlighted that relatively few formal learning opportunities around uncertainty exist, with arts-based learning[10] and clinical teaching tools (e.g., SNAPPS)[11] as notable exceptions. There was, however, an indication that learning around uncertainty can take place more informally, e.g., during problem-based learning, simulation-based learning, and other teaching strategies that involved group processes and/or reflective practice. This finding is supported by a recent scoping review by Patel et al.[12], which concluded that problem-based learning, medical humanities and simulation-based learning seemed to help students to build uncertainty tolerance. The authors also highlighted that some opportunities for learning around uncertainty, e.g., high fidelity simulation or assessment situations, could provoke unpleasant feelings for students. This latter finding appears also in the simulation-based learning literature, which proposes that both the pleasant and unpleasant emotions experienced by students can be harnessed for learning[13,14]. It is likely that inviting students into simulation activities that provoke a level of uncertainty or stress can help to prepare them for real-world challenges, with the important caveat that such learning events are designed and facilitated with expertise and attention to psychological safety[15].

This review also supported the idea that learners appear to develop their capacity to manage uncertainty as they progress through their training. Although the mechanism behind this is not clear, several studies refer to the phenomenon as a "maturation process"[16,17]. Some authors have suggested that an individual's uncertainty tolerance may develop as a result of experience and exposure to uncertain situations[18]. Others suggest that students' perceptions of healthcare undergo a major transition, moving from more "black or white" thinking at the start of their education, to a more nuanced awareness of the limits of their own knowledge, and those of medical science in general, in the latter part of their training[19]. Despite a lack of detail on how individuals develop a capacity to manage uncertainty, it is clear that the evidence supports a shift in conceptualising uncertainty management from one of a fixed personality trait to one of a mutable, potentially teachable competence[20].

To our knowledge, our research is the first to examine teaching and learning related to uncertainty across multiple health professions. Overall, our findings suggest that

undergraduate health professions students meet with uncertainty at many different stages of their training but that existing learning opportunities around the topic tend to be scarce and of an informal nature. We propose that learning around uncertainty might be facilitated by harnessing specific teaching strategies, especially those which provide an opportunity for reflection, e.g., simulation-based or problem-based learning.

WHAT ATTRIBUTES MIGHT HELP UNDERGRADUATE HEALTH PROFESSIONS STUDENTS TO MANAGE UNCERTAINTY?

Our research also set out to explore the attributes that might help undergraduate health professions students to manage uncertainty. To do so, we used a taxonomy of uncertainty[1] to discuss and analyse typical examples of the uncertainties faced by students, as depicted through role-played scenarios. Using this approach, a group of health professions educators identified a series of attributes (i.e., knowledge, skills and attitudes) which could help students to manage uncertain situations.

With respect to knowledge, the educators reported that students would benefit from a firm foundation of medical knowledge, a greater understanding of their role within the healthcare setting, and better insight as to the nature of uncertainty itself. With respect to skills, these included communication skills, emotion regulation, problem solving, information management, ethical decision making and an ability to self-assess. Our findings are in line with those of Kerr et al.[21] who found that, during the Covid-19 pandemic, students used information-seeking, emotional support (e.g., spending quality time with family) and drawing on their social network as strategies to cope with uncertainty. Finally, with respect to the attitudes that might help students to manage uncertainty, these included: openness, adaptability, positivity, and a growth mindset. Several of these attitudes have appeared elsewhere in the literature. For example a North American study of internal medicine residents found that those "...with a growth mindset were more comfortable with making their perceived weaknesses visible and embraced uncertainty"[22,p.271]. Additionally, ten Cate et al.[23] – in a further paper concerned with the uncertainties provoked by Covid-19 – argues that medical students can and should be trained for adaptability.

The study also cast light on how learners may be helped to develop such attributes within their medical training. For example, our findings highlighted the centrality of the educator in assisting students to build constructive approaches to uncertainty. The educators in this study acknowledged their influence on students' approaches to uncertainty through mentoring and role-modeling, whilst also displaying – in many instances – a drive to reduce or remove the uncertainties faced by students in the scenarios. This resonates with the "culture of certainty" highlighted in Chapter 2. This preference for certainty within healthcare has been described widely within the literature. As Han et al.[24(p.275)] explain: "Physicians and other health care providers manage these effects and their experience

of uncertainty itself through various strategies, but principal among these is the effort to seek information to reduce uncertainty. Nearly every major clinical activity that physicians undertake—diagnostic, prognostic, and therapeutic—is part of this overarching effort." Our findings here suggest that this drive to reduce uncertainty extends beyond clinical activities into those that relate to teaching and learning. Other authors have highlighted a growing preference for single best answer assessments and an overreliance on the "linear" approach of PowerPoint presentations, within health professions education[25,26]. Thus, it is possible that educators may, inadvertently, role model behaviours that seek to reduce uncertainty at times when to "sit with it" may lead to better outcomes. This may have unintended consequence with respect to supporting students to develop the attributes which will help them to manage uncertainty.

Our research did, however, highlight the value of discussing issues of uncertainty and its management at a small group level. Han and colleagues' taxonomy of uncertainty[1] (2011) provided a useful tool which provoked dialogue and shared reflection, allowing individuals to appreciate the myriad perspectives and approaches that exist when tackling challenging situations. Indeed, such interactions can help us to explore the nuances of clinical uncertainty, distinguishing between situations that would benefit from reducing uncertainty and those where it should be acknowledged and tolerated. This perspective is supported by other authors who highlight the importance of shared reflection in fore-grounding uncertainty in health professions education[12,27,28]. Overall, our research provides guidance as to what attributes could helpfully be addressed within medical school curricula, and how educators might support learners in development of the same.

WHAT ARE MEDICAL STUDENTS' EXPERIENCES OF BUILDING AND PLAYING A DIGITAL EDUCATIONAL ESCAPE ROOM DEVELOPED USING AN ONLINE DESIGN-THINKING PROCESS?

Our opening study, described in Chapter 2, highlighted the potential of simulation-based learning as a method of facilitating health professions students learning around uncertainty. We used a DBR approach to harness this finding, driving the development of a simulation activity, specifically a DEER, which could provide a practical educational solution. We were keen to explore the experiences of our student cohort, both those who had helped to construct the escape room, and those who had play-tested prototypes. In Chapter 4, we described the development and testing of an initial prototype escape room. This study provided early evidence that a DEER could provide an authentic but "safe" environment where student game players could test out strategies and engage in shared reflection. The students reported that the DEER had helped them to reach important insight around managing uncertainty such as "going with your gut," and the value of taking a shared approach to managing uncertainty (i.e., learning to appreciate the different strengths, skills and perspectives of others). Notably, some students reported that they had failed to learn

about uncertainty during game play and made specific recommendations on how the game could be improved. For example, it was suggested that there should be stronger links between the game's puzzles and the evidence base around uncertainty, an idea that aligns with existing advice for educational escape games. As stated idea by Veldkamp et al.[29, p.1223]: "a boundary condition for [the use of escape games] in education is that puzzles need to be aligned with the curriculum, and learners need their subject knowledge and skills to reach the intended learning goals."

Our DBR approach also invited us to widen our exploration of the DEER learning environment beyond the confines of play-testing an individual prototype within a specific context. Thus, we were motivated to investigate the students' experiences of building of the game itself, as reported in Chapter 5. Here, we looked more broadly at the online design-thinking process, using a lens of psychological safety to examine the student design team members' experiences of sharing ideas, making mistakes, taking risks, and discussing problems in the online setting[30]. There is a distinct gap in the existing literature around how creative team processes can be supported in virtual settings, and our findings suggested that psychological safety may play an important role in this context. Our student game-builders shared their experiences, reporting that effective facilitation and leadership, as well as an attention to team formation through social activities and ice-breakers, had helped them to reach a state of psychological safety within the group. Conversely, the difficulties of connecting online rather than face-to-face, the fear of speaking up in virtual environments and cultural differences emerged as barriers. Overall, this work lead us to conclude that the establishment of psychological safety in an online design-thinking setting allows team members to collaborate effectively, and feel more empowered to engage in creative work including the inherent uncertainties that this involves. Indeed, this study also provided important information about the level of uncertainty experienced by the students when engaging with the online design-thinking process. Whilst the overall project set out to create a resource that would facilitate medical students' learning around uncertainty, we also concluded that the design process itself had helped our student design team members to build capacities in this domain. This finding is supported by literature which highlights the potential for design-thinking education to provide a natural environment for learners to engage with uncertainty and ambiguity[31].

In summary, our work suggests that digital educational escape rooms offer fruitful opportunities for health professions students to engage with, and learn about, managing uncertainty. These opportunities exist at different levels, with both game-play and game-building presenting valuable uncertainty-provoking experiences for students.

HOW CAN A DIGITAL EDUCATIONAL ESCAPE ROOM BE USED TO FACILITATE LEARNING AROUND MANAGING UNCERTAINTY FOR UNDERGRADUATE MEDICAL STUDENTS?

Having established the potential of a DEER learning environment to facilitate learning around uncertainty, we were keen to probe further the nuances of the processes involved. Data from the preliminary round of play-testing was used to inform a further iteration of the escape room, and this second prototype was tested through a mixed methods study reported in Chapter 6. Here, our findings verified those from the previous play test with a further cohort of students reporting that they considered the DEER an effective way to facilitate their learning around uncertainty. The students described ways that the game had triggered multiple cognitive and affective experiences of uncertainty for them. They were also able to discuss how the game had helped them to adopt constructive approaches to uncertainty, many of which seemed to resonate with the real-world challenges they face in clinical settings (i.e., making sense of ambiguous information, engaging in decision-making under time pressure, and building trust quickly with unfamiliar people).

Affective experiences of uncertainty were particularly salient, and the students highlighted that the game provoked a wide variety of emotions including anxiety, frustration, curiosity and excitement. These findings support a growing awareness of the potential of DEERs to provide opportunities for students "to deal with… intense negative emotions, in particular fear or disgust, to move forward"[33,p.16]. The curation of emotional experiences within digital learning environments is an emerging area of research interest. For example, Arguel et al.[34] highlight that digital learning environments can be designed to detect when, and to what extent, learners are experiencing confusion, thus supporting deeper cognitive engagement but avoiding a negative spiral into learner frustration or boredom. As health professions' education becomes increasingly digitised, a situation catalysed by the Covid-19 pandemic, it is likely that educators and researchers will benefit from a greater understanding of how to harness emotions for learning in virtual learning environments.

Overall, our research suggests that a particular strength of DEERs, with their propensity to trigger cognitive and affective responses, is to provide a learning opportunity whereby educators can engage students in problem-solving and shared decision-making while immersed in a controlled, uncertainty-provoking environment.

WHAT CAN WE LEARN FROM APPLYING COMMUNITY OF INQUIRY TO THE DEER LEARNING ENVIRONMENT?

Our research also aimed to advance existing knowledge around how learning takes place within DEERs. Our chosen approach, DBR, encourages researchers to further existing theoretical understanding[35]. Here, we wanted to probe if and how the pedagogical framework CoI[2] could be applied to the DEER learning environment. In Chapter 6, we

highlighted that CoI appeared to have a natural resonance with DEER learning environments and multiple indicators of the three domains of CoI, cognitive, teaching and social presence, were observed. Within the DEER, social presence was evidenced by the students' ability and willingness to engage with each other using open, informal communication, and their expression of a wide range of emotions. Teaching presence was visible in the way that the facilitator had designed the game, and used prebrief and debrief sections to contextualise the game play. Teaching presence was also visible in the peer-peer learning that took place within the small-group breakout rooms. This latter finding connects with the broader CoI literature where a need to recognise the role of students as teachers has been proposed as a "vital question" for proponents of this conceptual framework[36,p.27]. However, with respect to cognitive presence, our findings were more ambiguous. Whilst indicators of cognitive presence were suggested in the puzzle-solving efforts of the students, it is difficult to ascertain whether or not these activities represented an example of the students "[constructing] meaning through sustained reflection and discourse," which is a hallmark of authentic cognitive presence[2,p.11].

Overall, our findings suggest that CoI is a pedagogical model that has wide applicability to DEER learning environments and the framework can be used to analyse and predict how learning takes place in these collaborative online learning spaces. We propose that particular attention is paid to facilitating the development of cognitive presence in both the planning and implementation of DEERs.

IMPLICATIONS FOR THEORY

A hallmark of DBR is that it incorporates processes of reflection, whereby researchers engage in "retrospective consideration of the findings of evaluative activities"[35,p.161]. In this section, we outline the outcomes of this reflective practice with a specific focus on how our work contributes to expanding current theoretical understanding. We will discuss what our results tell us with respect to key theoretical frameworks that were used within the research, as well as present a set of design principles that resulted from the overall reflective process. The first conceptual framework of importance for this thesis was Han et al.'s[1] taxonomy of uncertainty. As mentioned previously, this conceptual model aims to characterise healthcare uncertainty according to its sources, issues, and locus. The taxonomy provides an "anatomical framework"[25,p.54] that has been used to analyse the uncertainty experienced by health professionals in diverse medical settings from genetics[37] through to management of traumatic brain injuries[38]. However, to our knowledge, this thesis documents the first use of the taxonomy within an educational setting. Our findings suggest that the functionality of Han et al.'s taxonomy extends from research into education, and can be used as a practical tool to engage learners in shared reflection and discourse around uncertainty. Indeed, the taxonomy seems to lend itself well to small group settings, representing a further extension of its functionality beyond one-to-one settings such as in-depth interviews[39,40]. This is

an important application since it can foster a more team-based approach to uncertainty whereby "sharing uncertainty fosters courage among team members by distributing the burden of uncertainty, which include not only its negative psychological effects but also the practical, moral, and legal responsibilities for managing it"[24,p.129]. Tools that can facilitate open discussion around uncertainty in team-based settings offer a key way forward in tackling uncertainty in healthcare at a systematic level.

The second theoretical framework to play a central role in this research was the CoI framework[2]. CoI is one of the most widely studied models of online learning[42]. However, since the roots of CoI are embedded within the domain of text-based communication (e.g., online forums) much of the research focuses on asynchronous learning. Relatively few studies explore CoI as a model that can be applied to synchronous learning settings. The research described in this thesis aimed to evaluate if and how CoI might be used to study the process of learning within online, collaborative synchronous settings. Our work suggests that CoI did, indeed, provide a valuable way of conceptualising how learning takes place in the novel DEER environments with the core elements of CoI, social, cognitive and teaching presence, discernible in multiple, diverse ways. Our data revealed a natural resonance between CoI and DEER learning environments, with evidence that much of the learning is mediated through peer-peer interactions. The research around DEERs, and escape games in general, highlights that game design often takes place without the clear application of a distinct educational theory[43]. Here, we propose that CoI may offer a valuable framework with which to design and test online escape games for learning. Our reflection on this research culminated in a set of design principles for building DEERs that are underpinned by CoI (Table 1). It is hoped that these design principles will be of value to, and can inform the future work of, researchers and practitioners in the domain of DEERs.

As a final consideration, the work outlined within this thesis also helped us to gain further theoretical understanding around the construct of psychological safety. We explored psychological safety, defined here as "the degree to which people view the environment as conducive to interpersonally risky behaviors like speaking up or asking for help"[44,p.66], as a key "ingredient" to successful online teamwork. Although not a conceptual framework in the strictest sense of the term, psychological safety has nonetheless has emerged as a popular way of analysing team-based interactions[45]. Many studies examine psychological safety within face-to-face settings but there is relatively less attention to the establishment and maintenance of psychological safety within online settings. Our results suggest that psychological safety is an important consideration in nurturing creative teamwork within virtual environments. An attention to psychological safety provides a foundation whereby online team members can share ideas, speak up and ask for help. This is especially important where hierarchical relationships with inherent power differences between individuals exist, e.g., those commonly found within education and medicine.

Table 1: Design principles for digital educational escape rooms that are underpinned by Community of Inquiry

CoI presence	Design principles
Cognitive	• Use an engaging storyline that evokes curiosity for learners • Explicitly align escape room puzzles with meaningful/purposeful learning outcomes • Provide challenging puzzles aligned with learners' developmental levels which provoke shared reflection
Teaching	• Open the game with a prebrief which provides clear instructions, encourages engagement and establishes a safe, supportive and playful learning environment • During the game, maintain learner engagement through responsive facilitation (e.g., technical support), and effective game design (e.g., hint strategy) • After the game, use a debrief to help learners to make sense of the activity, facilitating the resolution phase of cognitive presence as well as emotional closure for learners • Encourage engagement and peer-learning through consideration of small group size and composition, and team-work strategy • Assist learners who are not familiar with each other to build rapport (e.g., through introductions and ice-breakers) • Ensure that game play and the 'rules of engagement' align with the intended cognitive process, learners' behaviour, and learning outcomes
Social	• Use web-conferencing software with breakout room capability to facilitate small group interactions • Employ complementary game strategies, from social collaboration to healthy competition, optimising learners' engagement • Use puzzles to evoke emotions that increase arousal and positively impact on cognitive presence

IMPLICATIONS FOR EDUCATIONAL PRACTICE

Our reflective process also led us to consider the implications of our research for educational practice. These implications can be broadly arranged into two categories: facilitating learning around uncertainty in health professions education, and building digital educational escape rooms. In this section, we share practical advice with respect to these two categories and – in the latter case – offer highlights from a practitioner article that was presented in Chapter 7.

Facilitating learning around uncertainty in health professions education

The research presented in this thesis has highlighted that experiences of uncertainty are commonplace for health professions education students, and that they receive little formal training in this domain. Although the contributing factors for this are unknown, one reason may be that a "culture of certainty" exists for some healthcare teams, disciplines, or institutions[3,12]. If a team culture values certainty over uncertainty, this can limit individuals' ability to acknowledge and disclose uncertainties[46]. This represents a crucial barrier to implementing learning around uncertainty within a health professions education setting. Although specific guidance for culture change lies outside of the scope of this thesis, we propose that evidence-based approaches to organisational change may be useful, e.g., involving all staff, students and stakeholders in the change process, having a clear vision for change, and enlisting "change champions" with effective leadership skills[47,48]. We also suggest that the topic of uncertainty goes hand-in-hand with issues of fallibility and vulnerability and, consequently, any attempts to open a dialogue in this domain should

entail an attention to psychological safety. Taking time and effort to lower the stakes of these conversations, break down power hierarchies and engage in authentic listening can enable individuals, especially medical students and postgraduate trainees, to open up about the uncertainties that they experience[46].

dopting a holistic approach to facilitating learning around uncertainty needs the involvement of both educators and students. Educators play a crucial role in supporting students to build constructive responses to uncertainty. It is likely that they influence students' approaches to uncertainty both tacitly and explicitly through formal teaching, mentoring, tutor and pastoral care, as well as via role-modelling. However, we also recognise that educators may have had little training around uncertainty themselves, a topic that can feel emotion-laden and "high stakes". Thus, educators may benefit from developing their own confidence and competence in this domain. Although there is little empirical research on what training might be useful, we suggest that faculty development might helpfully address: understanding the nature of uncertainty within healthcare and health professions education; recognising one's own approaches to uncertainty; making choices in responding to uncertainty; and using models such as Han et al.'s[1] taxonomy of uncertainty and Hillen et al.'s[49] integrative model of uncertainty tolerance as practical tools in structuring training approaches. In facilitating students' learning around uncertainty, it is also important that educators understand that uncertainty is a common experience for all, although certain students (e.g., non-native language-speaking students) or points in the curriculum (e.g., at transitions between classroom and clinical education settings) are more likely to need greater attention. In addition, it appears that uncertainties can be experienced in different ways by students. Thus, at times in one's teaching practice it may be wholly appropriate to reduce uncertainty for students, e.g., offering clear instructions for new modules, or transition-to-practice supports for clinical students. At other times, it is preferable that students are helped to manage, and persist with, uncertain situations despite experiencing unpleasant emotions.

Our research also implies that it is possible, and advisable, to address and correct the reputation of uncertainty as a "neglected element" of health professions curricula[50(p.799)]. Our research suggests that there are many natural homes for uncertainty within existing curricula, including modules or courses which address professional identity, communication skills, ethical and clinical reasoning, and inter-professional education. With respect to the "what" of teaching uncertainty, there is little empirical evidence for specific content to include in health professions curricula. Our research suggests that topics which help students to develop specific knowledge (e.g., a greater understanding of their role, better insight as to the nature of uncertainty in healthcare), skills (e.g., communication, emotion regulation, problem solving, and self-assessment) and attitudes (e.g., openness, adaptability, positivity, and growth mindset) may be valuable. Moreover, our research findings suggest that students should be helped to: understand that uncertainty and ambiguity are commonplace within healthcare; recognise their own approaches to uncertainty; notice uncertainty in in their day-to-day lives;

adopt new mindsets on uncertainty (positive as well as negative; taking a stance of curiosity rather than anxiety); let go of perfectionism; know how to speak up when unsure; and make choices in responding to uncertainty.

With respect to the "how" of teaching, small group teaching strategies such as problem-based and simulation-based learning offer promising spaces for learners to engage with uncertainty. Scenarios and cases can be adapted to bring uncertain situations to life, and offer a valuable crucible for the shared reflection that can help students to recognise the different perspectives and approaches that are possible. This thesis describes the design and evaluation of a digital educational escape room that facilitates students' learning around uncertainty. Our research also highlights the value of engaging learners in creative or design processes in order to provide them with opportunities to interact with, and learn about, uncertainty.

Building educational digital educational escape rooms

Our research also provides insight on how to design and build DEERs that genuinely facilitate learning. We have presented practitioner recommendations in Chapter 7 and revisit some of the key points here.

A strength of DEERs is their inherent flexibility and they can be used to support learning in a wide variety of settings, and to address many different domains of knowledge and skills. In building an effective DEER, an important first step is reflecting on the reasons for choosing a DEER approach: what should the game achieve? what aspect of teaching will be augmented or improved through the game? For example, this strategy may be used to meet a specific teaching and learning requirement, e.g., supporting rapid teamwork or peer learning. In planning a game, it is also crucial to apply a relevant learning theory to inform the design. Although there are a wide variety of learning theories that can be applied (e.g., adult learning, experiential learning), CoI appears to offer a practical and comprehensive framework with which to guide the build of team-based DEER activities.

In building the game, a number of design elements which contribute to the overall "look and feel" of the DEER will be developed. These include the theme of the escape room, the storyline or narrative and individual puzzles or activities. Learners spend a considerable amount of time solving these puzzles, so it is important that these are representative of the indicative content of the goals of the expected learning. In other words, escape games support learning more effectively when game goals align with the learning outcomes[51]. It is also necessary to consider how the puzzles will fit together (i.e., their sequence) and what hint strategy can assist the learners who get "stuck" in their progress.

Developing a DEER through creating prototypes and testing these is highly recommended. By testing puzzles early and frequently, this provides important information about how

difficult and enjoyable each puzzle is. Play-testing can also help identify technical issues which could cause frustration and impede learning for the game players.

Our research also highlights that the game itself should be considered a single component of the overall learning experience, and that educators should carefully consider what prebrief and debrief components they will use to situate the game for the learners. Prebriefing allows the game to be placed in context, with game players benefitting from clear instructions and/or ice-breaker activities. Debriefing helps the players to consolidate learning, address any learning outcomes that may have been missed, and relate their learning in the game to real-world instances. Furthermore, the debrief section can help learners to achieve cognitive "closure" on their learning, as well as address any emotions that arose as a result of game play. Educators play an important role in making the prebrief and debrief sections "safe" for learners, and can support this through effective facilitation.

STRENGTHS AND LIMITATIONS OF THIS RESEARCH

Uncertainty is, in itself, a vague and ill-defined construct. Previous authors have highlighted that uncertainty research has been hindered by a heterogeneity of study designs and findings, with widespread confusion about tools with which to measure it[52, 53]. Thus, a strength of our research is that we adopted a systematic approach from the beginning with our opening scoping review. We deemed a scoping review appropriate as this approach is suited to circumstances "where evidence is extensive and widely dispersed (i.e., many different types of evidence), or emerging and not yet amenable to questions of effectiveness"[54,p.3]. We also used a broad search strategy, across a diverse range of health professions and an extended time period, so as to cast a wide net for empirical data that would be relevant to uncertainty in undergraduate education.

This attention to structure also led us to select a DBR approach overall. We wanted to use the findings from our preliminary research (i.e., the scoping review and uncertainty workshop study) to inform the development of an educational solution. The flexible nature of DBR allowed us to harness our learning and feed this into the design process of the DEER. This flexibility proved particularly useful in adapting to, and overcoming, the barriers to research presented by the Covid-19 pandemic[55].

Another strength of DBR is its capacity to act as a framework for combining and integrating research methods[56]. This allowed us to implement a variety of study designs with multiple data collection points, across different study cohorts which contributed to the trustworthiness of our findings. Furthermore, DBR also motivated us to advance existing pedagogical theory around online learning, helping us to avoid a common pitfall of health professions education,

i.e., engaging in research which asks *if* learning took place, rather than *how* or *why*[57].

With respect to limitations, we recognise that our scoping review focuses on undergraduate education in the English-speaking world and, as a result, risks excluding important findings in a topic, healthcare uncertainty, which can be heavily influenced by socio-cultural factors[58]. We also note that in developing and testing our DEER, our study cohorts were small and homogenous, with most game users coming from a single discipline (i.e., medical education) at a single institution (i.e., RCSI University of Medicine and Health Sciences). Furthermore, our purposive sampling strategies meant that our research participants were likely highly motivated to take part in both game building and game testing, which would likely impact our study results. Such circumstances are not uncommon in educational game design and in DBR more generally[59,60]. This does not preclude the ability of highly context-specific design-based studies to offer findings that are generalisable to other settings. By providing detailed information about a project, it is possible for others to decide whether or not an educational solution would be relevant to their own context. As explained by van den Akker[61,p.68] : "a detailed description of the process-in-context may increase the 'ecological' validity of the findings, so that others can estimate in what respects and to what extent transfer from the reported situation to their own is possible." This contributed to our motivation to offer an in-depth description of the game-building process in Chapter 4, as well as to offer practitioner recommendations in Chapter 7.

FUTURE RESEARCH

The research outlined in this thesis has highlighted that uncertainty is a commonplace and important topic with real-world effects for health professions learners. There are many studies that examine uncertainty in health professions education, however the evidence base is fragmented and heterogeneous. Future research would benefit from a more organised approach to measuring uncertainty and uncertainty tolerance. In addition, longitudinal studies which track students' or medical professionals' approaches to uncertainty over an extended period of time would offer a valuable addition to the literature, particularly those that can determine what is happening for the individual at a more granular level. This would assist researchers in understanding the "maturation process" which characterises the evolution of learners' approaches to uncertainty as they progress through their education[16,17]. There is also a need for future researchers to develop and test interventions that can facilitate learning around uncertainty, particularly those that delve into learners' emotional or affective experiences of uncertainty. The topic of epistemic emotions may offer researchers an entry point into this aspect of uncertainty and its impact on the learning process, in both face-to-face and digital learning environments[62]. Another potential line of enquiry is to identify any differences in outcomes associated with so-called "productive" and "unproductive"

uncertainties[63]. For example, is the uncertainty felt by a student in caring for a patient who displays unpredictable behaviour more helpful to learning than the uncertainty that arises should she miss an assignment deadline, and, if so, why?

With respect to advancing our research from the perspective of the design of DEERS, we would welcome the application of the game presented in this thesis in different settings. It is planned that the game will be released as an open educational resource under a creative Commons license, and will be available to other educators and researchers for use within their own teaching contexts. Such testing is an integral component of design research and helps to build more robust foundational theories. As stated by Plomp[64,p.34], "design principles and local (instruction) theories will be additionally powerful if they have been validated in the successful design of more similar interventions in various contexts."

CONCLUSION

Uncertainty is a frequent phenomenon encountered by health professions students during their undergraduate training, and they routinely confront situations characterised by ambiguity and unpredictability. The extant literature underscores the presence of a predominantly negative discourse surrounding uncertainty. Moreover, a culture of certainty appears to prevail, challenging well-intentioned educators in their efforts to impart knowledge in this domain. Nevertheless, it is important that students are helped to understand that uncertainty represents an inherent characteristic of healthcare and can, indeed, serve as a constructive force, driving behaviour and motivating change.

Our research highlights that contemporary health professions curricula offer scant formal educational opportunities to address uncertainty management. Currently, much learning appears to take place in informal settings, such as in problem-based learning environments or during clinical placements. In this thesis, we have explored a novel educational solution, a digital educational escape room, as a means to equip health professions students with the necessary skills to navigate uncertainty. This pedagogical approach offers a conducive learning environment wherein students can actively engage with and experience uncertainty. It fosters collective reflection, and learners can be encouraged to grapple with uncertainty both through playing and building these educational games.

Recent years have brought into stark relief the importance of uncertainty, as exemplified by the Covid-19 pandemic. This crisis has shattered any illusion of stability or predictability in our day-to-day lives, as well as those of our patients. With this in mind, there is a renewed imperative to address uncertainty and its management by healthcare professionals through pedagogical and curricular interventions.

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Appendix

SUMMARY

Uncertainty is impossible to avoid in the practice of medicine. Healthcare professionals must develop ways to navigate the ambiguity and complexity that are inherent to their day-to-day work. This thesis sets out to explore how learning around uncertainty can be nurtured within undergraduate health professions curricula. Overall, the research we outline here casts light on the learning environments that may support health professionals to develop constructive approaches towards uncertainty. Our work also provides a detailed investigation into how a novel online learning environment, the digital educational escape room, can provoke authentic cognitive and affective experiences of uncertainty for students, thus offering a promising space for learning.

Chapter 1 provides an introduction to the topic of uncertainty and its management in health professions education. This chapter outlines why uncertainty management is an important capability for health professionals, and introduces key literature which offers insight as to how this capability might develop within health professions education settings. This section also offers structural information about the thesis, with an overview of the problem definitions and research questions that our research seeks to address. We also introduce the design-based research approach adopted within the thesis, as well as the main theoretical frameworks have been used.

In seeking to explore how learning around uncertainty develops within health professions education, we aimed to establish what is currently known about this topic. **Chapter 2** describes a scoping review that examined the existing literature around how undergraduate health professions students learn to engage with uncertainty. The study design followed a systematic approach whereby five databases and over 5,000 health professions journal articles were examined. Ninety-seven articles were included in the final review. Through a process of thematic analysis, our findings suggested that experiences of uncertainty are commonplace for undergraduate health professions' students, and that these experiences are moderated by factors that relate to the individual student and, more broadly, to the education and clinical environments that they find themselves in. The findings also highlighted that few formal teaching strategies exist that directly support learning around uncertainty. In contrast, health professions students tend to meet learning around uncertainty more opportunistically, through teaching methods such as problem-based learning, clinical teaching, simulation, reflective practice and various small group activities.

Chapter 3 describes a constructivist qualitative study whereby the topic of uncertainty was explored through small group reflection. Thirty health professions educators engaged in an analysis of role-played student vignettes using a taxonomy of uncertainty before discussing their experiences in focus groups. The findings from this study highlighted that

students' uncertainties can be complex and multifaceted, with multiple sources and issues of uncertainty identifiable. Our findings also suggest that tools such as the taxonomy in question could offer structure to health professions educators and learners when addressing and discussing uncertainty in practice. A further outcome of this study was a list of attributes (i.e. knowledge, skills and attitudes) which could help undergraduate health professions learners to offer constructive approaches towards managing uncertainty. Examples of these attributes included an awareness of the nature of uncertainty within healthcare practice, an ability to recognise uncertainty, and adopting attitudes of adaptability, positivity, and resilience.

In **Chapter 4** we used the initial findings from our earlier research to explore the potential of an online learning environment, the digital educational escape room, to support medical students' learning around uncertainty. This chapter provided a detailed description of the design and build and an initial prototype of an escape room, as well as a report on its testing via a small-scale usability study. The prototype was built using an online design-thinking intervention with an educator-student design team working towards the design challenge, "How might we use a digital educational escape room to help medical students manage uncertainty during transitions into the clinical setting?" The prototype room was tested with 17 medical students and five content experts. The findings from this study highlighted that digital educational escape rooms do, indeed, offer a promising learning environment for health professions learners to engage with uncertainty. In addition, the research highlighted that online design thinking offered a practical way for geographically dispersed educator-student design teams to engage with "messy" educational development problems. Finally, this study uncovered multiple ways to develop the escape room further with player feedback to inform a subsequent iteration of the game.

Chapter 5 offered further insight as to how the online design-thinking environment influenced the build of our digital educational escape room. This chapter described a qualitative single-case study which used semi-structured interviews to investigate the experiences of nine student design team members. Our study findings here highlighted that the importance of psychological safety in the planning and implementation of online design-thinking learning environments. Furthermore, the achievement of psychological safety within the online design team was thought to have led to a variety of positive outcomes including enhanced creativity and collaboration, and encouraged our student team to engage with the uncertainty inherent within game design practices. Our data suggested that, in this context, psychological safety could be developed through an attention to collaborative environments, encouraging leadership, and paying specific attention to team formation. However, difficulties connecting online, fear of speaking, and cultural considerations could present barriers to the same.

In **Chapter 6** we reported on the development of a second digital educational escape room prototype. This mixed methods study sought to probe further the potential of the escape room to facilitate medical students' learning around uncertainty. In addition, the study aimed to advance knowledge around how such novel learning environments work by applying Community of Inquiry as a guiding conceptual framework. Twenty-two medical students took part in the study, and data collection involved multiple strands, including focus groups, game-play observations, and questionnaires. Our findings suggested that most participants (82%) agreed that the escape room supported their learning around uncertainty and its management. Participants reported that the escape room environment offered an authentic and emotion-evoking experience which could help them to gain novel insights and establish appropriate approaches in managing uncertainty. In addition, the study provided evidence that Community of Inquiry could be effectively applied to digital educational escape room learning environments. This chapter culminated with a set of design principles that aims to support future online learning scholars, researchers and game-builders.

This thesis supports the idea that digital games have a strong potential to support learning across a diverse range of cognitive, affective, and psychomotor domains in health professions education. However, a significant barrier to the roll-out of such technology is the trepidation of health professions educators who may feel that they lack the necessary expertise to build educational games. **Chapter 7** harnessed our research findings to provide practitioner guidelines for the design and development of digital educational escape rooms. This section offered a 'toolbox' that introduces health professions educators to digital educational escape rooms, and supports them to build a simple game that they can apply in their own teaching context.

Chapter 8 provided a summary and synthesis of the findings derived from the studies presented throughout this thesis. Overall, our findings have highlighted that uncertainty is a common experience for undergraduate health professions students, but that relatively few formal learning opportunities around this topic exist within contemporary curricula. In this chapter, we concluded that a novel online learning environment such as a digital educational escape room can provide a valuable setting for medical students to learn about uncertainty. Digital educational escape rooms can expose students to cognitive and affective experiences of uncertainty and provide space for students to engage in problem solving and shared decision making around this important topic. This chapter also provided a detailed description of the implications of our work for both theory and practice.

SAMENVATTING

Onzekerheid is onvermijdelijk in de praktijk van de (dier)geneeskunde. Zorgprofessionals moeten manieren ontwikkelen om te navigeren door de ambiguïteit en complexiteit die inherent zijn aan hun dagelijkse werk. Deze thesis heeft tot doel te onderzoeken hoe het leren rond onzekerheid kan worden gestimuleerd binnen curricula voor gezondheidszorgberoepen. Over het geheel genomen werpt het onderzoek dat we hier schetsen licht op de leeromgevingen die gezondheidszorgprofessionals kunnen ondersteunen bij het ontwikkelen van constructieve benaderingen ten opzichte van onzekerheid. Ons werk biedt ook een gedetailleerd onderzoek naar hoe een nieuwe online leeromgeving, de digitale educatieve escaperoom, authentieke cognitieve en affectieve ervaringen van onzekerheid voor studenten kan uitlokken, waardoor het een veelbelovende mogelijkheid biedt voor leren.

Hoofdstuk 1 biedt een inleiding op het onderwerp onzekerheid en de beheersing ervan in het gezondheidszorgsonderwijs. Dit hoofdstuk geeft aan waarom het kunnen omgaan met onzekerheid een belangrijke bekwaamheid is voor gezondheidszorgprofessionals en introduceert belangrijke literatuur die inzicht biedt in hoe men zich hierin kan bekwamen binnen het gezondheidszorgonderwijs. Deze sectie biedt tevens informatie over de opzet van de thesis, met een overzicht van de probleemdefinities en onderzoeksvragen die ons onderzoek beoogt aan te pakken. We introduceren daarbij de onderzoeksbenadering die in de thesis is gevolgd, evenals de belangrijkste theoretische kaders die zijn gebruikt.

Met als doel te onderzoeken hoe studenten zich ontwikkelen ten aanzien van het omgaan met onzekerheid binnen het gezondheidszorgonderwijs, hebben we geprobeerd vast te stellen wat er momenteel bekend is over dit onderwerp. **Hoofdstuk 2** beschrijft een verkenning van de bestaande literatuur over hoe studenten in de gezondheidszorg leren om met onzekerheid om te gaan. De onderzoeksopzet volgde een systematische benadering waarbij vijf databases en meer dan 5.000 artikelen werden onderzocht. Zevenennegentig artikelen werden opgenomen in de uiteindelijke review. Uit onze bevindingen bleek dat ervaringen met onzekerheid veelvoorkomend zijn voor gezondheidszorgstudenten, en dat deze ervaringen worden gemodereerd door factoren die verband houden met de individuele student en, breder gezien, met de onderwijs- en klinische context waarin ze zich bevinden. De bevindingen benadrukten ook dat er weinig formele onderwijsstrategieën bestaan die rechtstreeks de ontwikkeling ten aanzien van het omgaan met onzekerheid ondersteunen. In tegenstelling hiermee lijken studenten in gezondheidszorgberoepen meer opportunistisch in contact te komen met het leren omgaan met onzekerheid, via onderwijsmethoden zoals probleem gestuurd leren, klinisch onderwijs, simulatie, reflectieve praktijk en verschillende groepsactiviteiten.

Hoofdstuk 3 beschrijft een constructivistische kwalitatieve studie waarbij het onderwerp onzekerheid werd verkend via reflectie in kleine groepen. Dertig docenten werkzaam in gezondheidszorgopleidingen analyseerden nagespeelde studentenvignetten met behulp van een taxonomie van onzekerheid, waarna ze hun ervaringen bespraken in focusgroepen. De bevindingen van deze studie benadrukten dat onzekerheden van studenten complex en veelzijdig kunnen zijn, met meerdere te identificeren oorzaken en kwesties van onzekerheid. Onze bevindingen suggereren ook dat tools zoals de genoemde taxonomie structuur kunnen bieden aan docenten en studenten bij het aanpakken en bespreken van onzekerheid in de praktijk. Een verdere uitkomst van deze studie was een lijst van eigenschappen (dat wil zeggen kennis, vaardigheden en houdingen) die studenten kunnen helpen om constructieve benaderingen ten opzichte van het omgaan met onzekerheid te ontwikkelen. Voorbeelden van deze eigenschappen zijn onder andere een bewustzijn van de aard van onzekerheid in de gezondheidszorgpraktijk, het vermogen om onzekerheid te herkennen, en het aannemen van attitudes van aanpasbaarheid, positiviteit en veerkracht.

In **Hoofdstuk 4** bouwen we voort op de initiële bevindingen uit ons eerdere onderzoek om het potentieel van een online leeromgeving, de digitale educatieve escaperoom, te verkennen ter ondersteuning van het leren omgaan met onzekerheid van medische studenten. Dit hoofdstuk biedt een gedetailleerde beschrijving van het ontwerp en de bouw van een prototype van een escaperoom, evenals een verslag van de evaluatie ervan via een kleinschalige bruikbaarheidsstudie. Het prototype werd gebouwd met behulp van een online 'design-thinking' interventie met een ontwerpteam bestaande uit docenten en studenten dat werkte aan de ontwerpopdracht: "Hoe kunnen we een digitale educatieve escaperoom gebruiken om medische studenten te helpen bij het omgaan met onzekerheid tijdens de transitie naar de klinische setting?" Het prototype werd getest met 17 medische studenten en vijf inhoudsdeskundigen. De bevindingen van deze studie benadrukten dat digitale educatieve escaperooms inderdaad een veelbelovende leeromgeving bieden voor studenten in het omgaan met onzekerheid. Bovendien liet het onderzoek zien dat online 'design-thinking' een praktische manier biedt voor geografisch verspreide ontwerpteams.

Hoofdstuk 5 biedt verdere inzichten in hoe de online 'design-thinking' omgeving invloed had op de ontwikkeling van de digitale educatieve escaperoom. In dit hoofdstuk wordt een kwalitatieve single-case studie beschreven die gebruikmaakte van semi-gestructureerde interviews om de ervaringen van negen leden van het studentenontwerpteam te onderzoeken. De onderzoeksresultaten benadrukken het belang van psychologische veiligheid bij het ontwerp en implementatie van online 'design-thinking' leeromgevingen. Bovendien laten de resultaten zien dat het bereiken van psychologische veiligheid binnen het online ontwerpteam heeft geleid tot verschillende positieve uitkomsten, waaronder verbeterde creativiteit en samenwerking, en tegelijkertijd onze studenten aanmoedigde om zich bezig te houden met de inherente onzekerheid binnen game-ontwerppraktijken. De

resultaten suggereren dat psychologische veiligheid in deze context ontwikkeld kan worden door aandacht te besteden aan samenwerkingsomgevingen, leiderschap te stimuleren en specifieke aandacht te besteden aan teamvorming. Desalniettemin kunnen moeilijkheden bij onlineverbinding, spreekangst en culturele overwegingen voor belemmeringen zorgen.

In **Hoofdstuk 6** rapporteren we over de ontwikkeling van een tweede prototype van een digitale educatieve escaperoom. Deze 'mixed-method' studie beoogde het potentieel van de escaperoom om het omgaan van medische studenten met onzekerheid te vergemakkelijken nader te onderzoeken. Bovendien beoogde de studie de kennis rondom hoe dergelijke nieuwe leeromgevingen werken te bevorderen door 'Community of Inquiry' toe te passen als leidend conceptueel kader. Tweeëntwintig medische studenten namen deel aan de studie. De dataverzameling omvatte meerdere elementen, waaronder focusgroepen, observaties van het spel en vragenlijsten. De bevindingen suggereren dat de meerderheid van de deelnemers (82%) het ermee eens was dat de escaperoom hun ontwikkeling ten aanzien van het omgaan met onzekerheid en de beheersing ervan ondersteunde. Deelnemers meldden dat de escaperoom-omgeving een authentieke en emotie-opwekkende ervaring bood, wat hen kon helpen nieuwe inzichten te verwerven en geschikte benaderingen in het omgaan met onzekerheid vast te stellen. Daarnaast bood de studie bewijs dat 'Community of Inquiry' effectief kon worden toegepast op digitale educatieve escaperoom-leeromgevingen. Dit hoofdstuk wordt afgesloten met een reeks ontwerpprincipes die tot doel hebben toekomstige onderwijswetenschappers en 'game designers' te ondersteunen.

Deze scriptie ondersteunt het idee dat digitale games een groot potentieel hebben om leren te ondersteunen in een divers scala aan cognitieve, affectieve en psychomotorische domeinen in het gezondheidszorgonderwijs. Een significante belemmering voor de implementatie van dergelijke technologie is echter de terughoudendheid van gezondheidszorgprofessionals die wellicht het gevoel hebben dat ze niet over de nodige expertise beschikken om educatieve games te ontwikkelen. In h**oofdstuk 7** worden op basis van de onderzoeksresultaten praktijkaanbevelingen gegeven voor het ontwerp en de ontwikkeling van digitale educatieve escaperooms. Deze sectie biedt een 'gereedschapskist' die gezondheidszorgprofessionals de weg wijst met digitale educatieve escaperooms en hen ondersteunt bij het bouwen van een eenvoudig spel dat ze kunnen toepassen in hun eigen onderwijscontext.

Hoofdstuk 8 biedt een samenvatting en synthese van de bevindingen die voortkwamen uit de studies gepresenteerd in deze thesis. Over het algemeen benadrukken onze bevindingen dat onzekerheid een veelvoorkomende ervaring is voor studenten in de gezondheidszorgsberoepen, maar dat er relatief weinig formele leermogelijkheden bestaan rond dit onderwerp binnen hedendaagse curricula. In dit hoofdstuk concluderen

we dat een nieuwe online leeromgeving zoals een digitale educatieve escaperoom een waardevolle setting kan bieden voor medische studenten om over het omgaan met onzekerheid te leren. Digitale educatieve escaperooms kunnen studenten blootstellen aan cognitieve en affectieve ervaringen van onzekerheid en ruimte bieden voor studenten om zich bezig te houden met probleemoplossing en gezamenlijke besluitvorming rond dit belangrijke onderwerp. Dit hoofdstuk biedt tevens een gedetailleerde beschrijving van de implicaties van ons werk voor zowel theorie als praktijk.

CURRICULUM VITAE

Jenny Moffett was born in Birmingham, UK, in 1976. She returned to Ireland with her family in 1980 and attended school at St. Peter's N.S., Drogheda Grammar School, and Armagh College of Further Education. Jenny enrolled at the Royal Veterinary College, London in 1995. During her time there, she was awarded the Cotchin Prize for Pathology, and the Schering Plough Prize for Final Year Studies, graduating with honours in 2000. Jenny spent several years in clinical practice in the UK before taking time out to travel and locum.

Twelve months and 11 countries later, Jenny worked as a visiting vet in Birmingham, before returning to Ireland to pursue a Master's in Science Communication at Dublin City University. Following graduation, Jenny was appointed Editor of the Irish Veterinary Journal and began working with the communication skills team at the School of Veterinary Medicine, University College Dublin. In 2010, Jenny co-edited the first evidence-based communication skills textbook for veterinarians, Handbook of Veterinary Communication Skills, with her friend and colleague Dr Carol Gray. Jenny was then appointed Director of Communication Skills and Assistant Professor at Ross University School of Veterinary Medicine, St. Kitts, where she founded the university's inaugural communication skills programme. Jenny worked with faculty and administration to build an integrated communication skills curriculum, establish a community of simulated patients and develop a purpose-built communication skills laboratory.

In 2014, Jenny and her growing family returned to the UK to take up the position of Senior Tutor in Professional Skills at the new School of Veterinary Medicine, University of Surrey, where she was appointed Programme Director for the BVMSci programme in 2015. In keeping with her life-long challenge to commit to one country, Jenny returned to Ireland, undertook a Diploma in Mentoring and Coaching, and founded her online coaching and continuing education company, SkillsTree. Through SkillsTree, Jenny and her team, notably Dr Jenny Lynden, have supported hundreds of healthcare professionals and students to develop communication and self-care skills that they use daily in their careers.

Since 2018, Jenny has worked as a Faculty Developer and Educationalist in the Health Professions Education Centre at RCSI University of Medicine and Health Sciences, where she is Programme Director for the Postgraduate Diploma in Health Professions Education. Her PhD studies were funded by the Irish Medical Council/Irish Network of Healthcare Educators RIME (Research in Medical Education) grant, the RCSI StEP (Student Engagement and Partnership) initiative and the RCSI Staff Development Fund. Her research has been awarded national and international awards, including the 2021 Irish Network of Healthcare Educators Research Presentation Award, the 2023 John Kelly Award for Universal Design for Learning and the 2024 Clinical Teacher IMPACT Award.

At the heart of her career, Jenny enjoys helping others to find the "aha!" moments that transform their lives. She lives in Co. Louth, Ireland with her two sons, Oisín and Dara.

PRESENTATIONS RELATED TO THIS THESIS

Moffett, J., Hancock, J., and Hammond, J. (2024). Choppy waters: how educators can support their learners to navigate healthcare uncertainty, ASME, Online on April 24.

Moffett, J. (2024). The creativity cure: design thinking for health professions educators. Workshop at INHED (Irish Network of Healthcare Educators), Dublin on January 24.

Moffett, J. & Biagini, A. (2023). Debriefing educational escape games. Lessons from health professions education. Research presentation at ECGBL (European Conference on Games Based Learning), University of Twente, Enschede, on October 5.

Moffett, J. (2023). Escape rooms for learning: Under the bonnet. Invited speaker at “Escape rooms in education: showcase and celebration of practice”, Herriot-Watt University, Online, on June 9.

Moffett, J. (2023). A clinician’s guide to uncertainty. Invited speaker at Oculus Insights Veterinary Business Summit, Amsterdam, on May 23.

Moffett, J. (2023). The novel use of a digital educational escape room to develop learners’ capacity to manage uncertainty during medical school transitions. Research presentation at INHED (Irish Network of Healthcare Educators), Queen’s University Belfast, on March 30.

Moffett, J. (2023). Using Community of Inquiry to explore learning in digital educational escape rooms. Research presentation at INHED (Irish Network of Healthcare Educators), Queen’s University Belfast, on March 30.

Moffett, J. (2023). Preparing health professions learners to work with uncertainty using design-based research. Research presentation at IDEA (Irish Doctoral Education Academy), Queen’s University Belfast, on March 28.

Moffett, J. (2023). Applications of simulation-based learning: The human touch. Keynote speech at InVeST (International Veterinary Simulation in Teaching), St. George’s University, Grenada, on February 5.

Moffett, J. (2023). Messy medicine: Using simulation to support learning around uncertainty. Workshop at InVeST (International Veterinary Simulation in Teaching), St. George’s University, Grenada, on February 4.

Moffett, J. and Doyle, M. (2022). Digital educational escape rooms: What, why and how? Workshop at AMEE (The International Association for Health Professions Educators), Online, on August 31.

Moffett, J. (2022). Digital educational escape rooms. Viewing learning through the Community of Inquiry framework. Research presentation at VetEd Conference, Nottingham University, on July 7.

Moffett, J. (2022). Supporting medical students to build constructive approaches to working with uncertainty during their undergraduate education: a design based research approach. Research presentation at IDEA (Irish Doctoral Education Academy), Queen's University Belfast, on April 7.

Moffett, J. (2022). The novel use of a digital educational escape room to develop learners' capacity to manage uncertainty during medical school transitions. Research presentation at INHED (Irish Network of Healthcare Educators), University of Limerick, Online, on March 24.

Moffett, J. (2021). Getting started with scoping reviews. RCSI Educate Hub, Dublin, Online, on December 8.

Moffett, J. (2021). Community of Inquiry: Facilitating psychological safety within an online faculty development initiative. Research presentation at AMEE (The International Association for Health Professions Educators)/ The 6th International Conference on Faculty Development in the Health Professions, Online, on August 29.

Moffett, J. (2021). Adventures with uncertainty. RCSI Educate Hub, RCSI Dublin, Online, on May 6.

Moffett, J. (2021). Unpacking uncertainty in health professions' education: What knowledge, skills and attitudes can help learners to navigate uncertain situations? Research presentation at INHED (Irish Network of Healthcare Educators), UCD, Online, on March 11.

Moffett, J. (2020). How undergraduate health professions' students experience and respond to uncertainty. Research presented at ASME (Association of Medical Educators), UK, on October 1.

Moffett, J. (2020). Stirred but not shaken. Helping learners to navigate uncertain situations. Workshop presented at INHED (Irish Network of Healthcare Educators), TCD, Dublin, on February 13.

Moffett, J. (2019). What do we know about uncertainty, and teaching around uncertainty, in health professions education? A scoping review. Research presentation at INMED (Irish Network of Medical Educators), NUI Galway, on February 7.

PUBLICATIONS RELATED TO THIS THESIS

PEER REVIEWED PUBLICATIONS

Moffett, J., Cassidy, D., Collins, N., Illing, J., de Carvalho Filho, M. A., & Bok, H. (2023). Exploring medical students' learning around uncertainty management using a digital educational escape room: a design-based research approach. Perspectives on Medical Education, 12(1): 86–98.

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NON PEER REVIEWED PUBLICATIONS

Moffett, J. (2022). Five tips for using design thinking to transform your academic practice. Times Higher Education, February 8, 2022.

ACKNOWLEDGEMENTS

This thesis, both the content and process, has helped to transform my approach to managing uncertainty. What started with an attempt to satisfy an intellectual curiosity, progressed into a whole-scale change in the way that I view, and navigate, the world. This transformation would not have been possible without a community of kind and talented individuals who have supported me. I would like to share my sincere gratitude to those individuals here.

First and foremost, I would like to thank my two supervisors, Harold Bok and Marco Antonio de Carvalho-Filho. I couldn't have asked for more knowledgeable and generous supervisors. Harold, Marco, you took a brave leap of faith in welcoming a non-traditional (this makes me sound younger than "mature") candidate with the curveball topic of an online escape room. From the moment we began working together, I felt a sense of relief to know I had a supportive and expert team behind me. Harold, thank you in particular for being so present and encouraging in your communication. I have felt part of the Utrecht University and the Faculty of Veterinary Medicine communities despite the geographical distance, and you have made all the difference in this. Marco, your knowledge and expertise in educational innovation has been indispensable. Both of you have taught me so much, not least how to be an excellent PhD supervisor.

I would also like to thank the many member of RCSI's HPEC (Health Professions Education Centre) past and present who have supported me in my studies. I couldn't have been better placed to complete a PhD, surrounded by learned, helpful and enthusiastic colleagues. My deepest thanks go Richard Arnett, Catherine Bruen, Dara Cassidy, Martina Crehan, Caroline Delany, Michelle Doyle, Gareth Edwards, Jan Illing, Erica Smyth, Helen Kelly, Fiona Kent, Ciaran McCarthy, Vicki O'Donnell, Geraldine Regan, Mary Smyth, Clare Sullivan, and Teresa Pawlikowska. Particular thanks go to Dara for offering me practical support and authentic expertise in building the foundations of this research approach.

The body of work that is described within this thesis represents a vast team effort. I would like to thank all of my colleagues that worked with me to extend the evidence base around uncertainty and escape rooms. This begins with the wonderful RCSI students that gave up their time to build and test the escape room: Zara Ahmed, Harry Cummins, Smruthik Goka, Lauren Li, Ruth Little, Aditya Patki, Romket Pornsakulpaisal, Shaudee Salari, Vitallia Sooknarine, and Yap Sook Woon. I still can't quite believe what we were able to achieve. Despite the tricky backdrop of a global pandemic, and a team that worked across three different continents and multiple time zones, we were able to nurture a creative online space and build an immersive learning environment. I hope that in your new medical careers you will be able to look back on this time, and what you achieved, to understand that each and every one of you have an enormous capacity for invention, creativity, and thoughtful

problem-solving. Harry, if you ever feel like branching out, know that there is another career in theatre or the big screen, just waiting for you!

Next, I would like to express my gratitude to the fantastic colleagues who helped to tell the story of our work: Elizabeth Armitage-Chan, Naoise Collins, Síle Kelly, Jenny Hammond, Ruth Little, and Paul Murphy. Jenny deserves a special mention as her own doctorate in uncertainty was inspirational to me. Combined with Jason Hancock's PhD, it seems that if your name begins with "J" then uncertainty is probably a fruitful doctorate topic (n=3).

I would also like to thank the many talented individuals who contributed to this body of work behind the scenes. Design-based research is a rewarding but intensive process. There are many moving parts, processes and data streams. It is, therefore, a "team sport", and this research has given me the privilege of working with many generous, hard-working and gifted people. Thank you to Anique Atherley, Caitriona Cahir, Yeukai Chikwamba, Andrea Doyle, Mark Ennis, Heidi Eukel, Michelle Flood, Sarah Flynn, Randy Garrison, Emma Grigg, Paul Han, Aisling Kerr, Ray Lohan, Brian Marron, Julia Morris, Gozie Offiah, David Sklar, Muirne Spooner, Ellen Stuart, Norm Vaughan, Alice Veldkamp, and Joanna Zawadzka. A particular high point for me was a phone call with Norm that rescued me from the existentialist whirlpool of conceptual frameworks. Norm, who took my Community of Inquiry crisis call while he was on vacation and his hotel room was being cleaned, proves that little can rattle an online educator!

It would be fair to say that my PhD journey began many years before the research itself. I would like to thank Andrew Knight who first planted the seeds of PhD by Publication in my head. Equally influential was Gail Anderson whose gentle leadership encouraged me on the path of scholarship. Thank you also to my IDEA and VetEd colleagues for their support, particularly Tim Dornan for connecting me with the Utrecht team and Diane Cashman for walking the path with me (and I don't just mean Nottingham airport!). Thank you also to INHED, the Medical Council of Ireland and the RCSI Student Engagement and Partnership initiative, your financial support was critical in building this learning environment and enabling its communication internationally.

Thank you to the Utrecht University assessment committee, Wim Kremer, Daniela Salvatori, Marieke van der Schaaf, Karen Mattick and Diana Dolmans. I am very grateful that you would spend your valuable time to engage with this work and share your learning with me. Thank you in particular to Debbie Jaarsma for welcoming me into the Utrecht fold, and, as for Harold and Marco, in taking that leap of faith.

I am very fortunate to be joined in my life by a plethora of strong, intelligent and witty ladies: Janet Beeler, Alessandra Biagini, Fiona Brogan, Fidelma Burkley, Fernanda Castillo Alcala,

Andrea Doyle, Karen Dunne, Robin Farrell, Emma Kelly, Carol Gray, Emma Grigg and Ruth Little (so influential that this is your third mention!), Jenny Lynden, Ronni Morgan, Agnes Murray, Joan Ni Gabhann-Dromgoole, Shari Thorpe (yes Shari, I added “plethora” just for you). These have been six of the most transformative years of my life, and each one of you has puzzled with me, shared thoughts, and laughed. Sometimes we find solutions and sometimes we don’t and that’s OK, another life lesson that I have taken from this work. I am so grateful to have each of you in my life.

Before these acknowledgements turn into a “golden cleric” moment, I would like to finish with thanking my family, Robert, Dolly and Graham for their love and support in my studies. Finally, I would like to dedicate this thesis to Oisín and Dara. Oisín, with your intricate knowledge of video gaming, and Dara, with your amazing sense of humour, you have helped me so much in this work. Beyond this, you have travelled with me across three countries, navigated the uncertainties of life, and I enjoy your fun and intelligence every day. Finally, Otto (2008-2024) you are gone but not forgotten! No-one supervised quite as much of my work as Otto. I am thankful for the countless photos I have of post-it notes, printouts, concept maps and laptop screens, each one graced by a little brown dog, my writing partner.