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RESEARCH REPORT

Fostering uncertainty tolerance in anatomy education: Lessons learned from how humanities, arts and social science (HASS) educators develop learners' uncertainty tolerance

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Abstract

Uncertainty tolerance, individuals' perceptions/responses to uncertain stimuli, is increasingly recognized as critical to effective healthcare practice. While the Covid-19 pandemic generated collective uncertainty, healthcare-related uncertainty is omnipresent. Correspondingly, there is increasing focus on uncertainty tolerance as a health professional graduate "competency," and a concomitant interest in identifying pedagogy fostering learners' uncertainty tolerance. Despite these calls, practical guidelines for educators are lacking. There is some initial evidence that anatomy education can foster medical students' uncertainty tolerance (e.g., anatomical variation and dissection novelty), however, there remains a knowledge gap regarding robust curriculum-wide uncertainty tolerance teaching strategies. Drawing upon humanities, arts and social sciences (HASS) educators' established uncertainty tolerance pedagogies, this study sought to learn from HASS academics' experiences with, and teaching practices related to, uncertainty pedagogy using a qualitative, exploratory study design. Framework analysis was undertaken using an abductive approach, wherein researchers oscillate between inductive and deductive coding (comparing to the uncertainty tolerance conceptual model). During this analysis, the authors analyzed ~386 min of data from purposively sampled HASS academics' (n = 14) discussions to address the following research questions: (1) What teaching practices do HASS academics' perceive as impacting learners' uncertainty tolerance, and (2) How do HASS academics execute these teaching practices? The results extend current understanding of the moderating effects of education on uncertainty tolerance and supports prior findings that the anatomy learning environment is ripe for supporting learner uncertainty tolerance development. This study adds to growing literature on the powerful moderating effect education has on uncertainty tolerance and proposes translation of HASS uncertainty tolerance teaching practices to enhance anatomy education.

KEYWORDS
ambiguity tolerance, Covid-19, gross anatomy education, medical education, pedagogy, qualitative research, teaching practices, uncertainty tolerance, undergraduate education

INTRODUCTION

The Covid-19 pandemic ignited a global collective uncertainty, demonstrating the extant and omnipresent nature of healthcare unknowns. Healthcare-related uncertainties also exist outside of the pandemic context. From clinical presentations, to diagnostic interpretation, to treatment responses and outcomes—healthcare uncertainties are ubiquitous. How healthcare professionals manage these uncertainties, known as uncertainty tolerance, becomes an essential clinical skill in dynamic, ever-changing healthcare environments. In recognition of this, there is an increasing focus on uncertainty tolerance as a healthcare graduate 'competency' (Osler, 1950; Geller et al., 1990; Harden et al., 1999; Simpson et al., 2002; Toohey et al., 2008; Englander et al., 2013; ACGME, 2015; GMC, 2018; Cumming & Ross, 2020; AAMC, 2021a, b), with many calling for evaluation of uncertainty tolerance as part of entrance into healthcare education programs and/or with program progression (Albanese et al., 2003; Geller, 2013; ACGME, 2015; AAMC, 2021b). Despite this desire to foster uncertainty tolerance in healthcare education, the impact of teaching practices on students' uncertainty tolerance remains embryonic (Moffett et al., 2021).

Uncertainty tolerance is a psychological construct referring to the way an individual perceives and processes information about ambiguous situations (i.e., stimuli) when confronted by an array of unfamiliar, complex, or incongruent clues (Budner, 1962; Furnham & Ribchester, 1995). This increasing desire to integrate uncertainty tolerance teaching practices across healthcare degrees (Luther & Crandall, 2011; Simpkin & Schwartzstein, 2016; Cooke & Lemay, 2017) can be challenging, as guidance on operationalizing and executing teaching practices supportive of uncertainty tolerance development remains limited (Rieckmann, 2012; Kim & Lee, 2018; Moffett et al., 2021). There is some recent research, though, that supports the relationship between uncertainty tolerance and education. In the context of Covid-19 pandemic teaching, university students' uncertainty tolerance was critical for their reported satisfaction during pandemic related educational changes (Grace et al., 2021), suggesting that (at minumum) uncertainty tolerance impacts learners' capacity to learn.

Anatomy is often one of the first foundational healthcare sciences students encounter in their professional education, and remains a science topic that students are vested in (Older, 2004; Moxham & Plaisant, 2007; Nabil et al., 2014; Triepels et al., 2018). Students preparedness for transitioning into healthcare education, where uncertainty is present, varies widely (Strout et al., 2018). Some students commencing their healthcare professional degrees are identified as markedly *in*tolerant of uncertainty (Han et al., 2015). Indeed, students largely appear to respond negatively to the initial phases of anatomy teaching when uncertainties are present (Stephens et al., 2021), supporting the notion that students entering healthcare education may not yet be prepared for the uncertainties facing them in their future careers.

The anatomy education learning environment stimulates uncertainty through human anatomy variations (Willan & Humpherson, 1999; Wheble & Channon, 2021; Cullinane & Barry, 2022), the breadth of anatomical knowledge (Swick, 2000), and the sociocultural threshold that student's experience through their first anatomy dissections (Stephens et al., 2021). Sources of uncertainty are not unique to anatomy education, however, as similar uncertainty stimuli exist across the entirety of healthcare education and future clinical practice (Hillen et al., 2017; Strout et al., 2018), justifying uncertainty tolerance as a core healthcare graduate competency (Osler, 1950; Geller et al., 1990; Harden et al., 1999; Simpson et al., 2002; Toohey et al., 2008; Englander et al., 2013; ACGME, 2015; GMC, 2018; Cumming & Ross, 2020; AAMC, 2021a, b).

Debates abound between the role of healthcare curricula in preparing healthcare students for real-world uncertainties versus teaching "certain" discipline content (White & Williams, 2017; Ilgen et al., 2019). For example, healthcare professional course selection processes typically favor those who excel at "single-best-answer" examinations (Sladek et al., 2019) and anatomy summative assessments mimic this selection by focusing on "rightness" and "wrongness" (Harrison et al., 2017; Bird et al., 2019), with the predominant form of anatomy examinations being multiple-choice and "spot" assessments (where students identify tagged structures on images, specimens or models) (Pandey & Zimitat, 2007).

This failure to support and assess learners' uncertainty tolerance may be negatively impacting their transitions to clinic and healthcare practice. Upon entering clinical rotations, students are confronted with a plethora of ambiguous stimuli and dynamic clinical contexts for which they appear underprepared (Fox, 1957, 1980; Han et al., 2011; Gheihman et al., 2020). While there are calls to improve healthcare learner uncertainty tolerance, a gap still remains in actioning this call (Luther & Crandall, 2011; Domen, 2016). This partition between healthcare teaching practices (e.g., content vs. uncertainty), and the realities of future careers filled with uncertainty appears to have detrimental effects on students' wellbeing (Hancock & Mattick, 2020).

There appear to be many relationships between healthcare practice and healthcare providers' uncertainty tolerance, with medical doctors being the primary focus of much of this research (Strout et al., 2018). Evidence suggests that healthcare providers' uncertainty tolerance impacts their approaches to ordering diagnostic tests and their use of resources (Lysdahl & Hofmann, 2009; Strout et al., 2018), as well as influencing their decision-making processes (Ghosh, 2004; Lysdahl & Hofmann, 2009; Burman et al., 2014). Furthermore, many uncertainty tolerance studies link low uncertainty tolerance

to burnout and emotional distress (Lally & Cantillon, 2014; Kimo Takayesu et al., 2014; Hancock & Mattick, 2020), and higher uncertainty tolerance to well-being (Kuhn et al., 2009; Cooke et al., 2013). Uncertainty tolerance may also be related to future medical speciality choice (Borracci et al., 2021), further supporting a potentially important role of uncertainty tolerance in healthcare education and preparation of the future healthcare workforce.

The modern healthcare uncertainty tolerance conceptual model (Hillen et al., 2017) proposes that an uncertain stimulus is perceived and responded across three domains (cognitive, emotional, behavioral) across a spectrum of negative to positive. This model includes a step where the perception, and thus related responses, can be modulated through so-called "moderators." These moderators are only generally described in the conceptual model (Hillen et al., 2017), and include factors such as age and prior experiences.

While education was not originally included in the modern conceptual uncertainty tolerance model, there is increasing evidence that education, including anatomy education, moderates uncertainty tolerance. Some studies suggest that learners' educational progression improves uncertainty tolerance (Han et al., 2015; Strout et al., 2018), while other research is beginning to elucidate how different types of educational styles impact uncertainty tolerance development (either fostering or hindering) (Nevalainen et al., 2010; Gowda et al., 2018; Moffett et al., 2021; Stephens et al., 2021). Findings across healthcare education suggest that teaching practices such as: team-focused learning activities (Stephens et al., 2021) and creating opportunities for reflective practice (Nevalainen et al., 2010; Gowda et al., 2018) foster learner uncertainty tolerance. In contrast, didactic stand-alone approaches appear to result in the opposite effect, by hindering learner uncertainty tolerance (Stephens et al., 2021).

There is evidence that HASS (humanities, arts and social sciences) disciplines and sub-disciplines foster uncertainty tolerance effectively through their teaching practices (García Ochoa et al., 2016; Haidet et al., 2016; Bentwich & Gilbey, 2017; Richardson, 2017; Felsman et al., 2020; García Ochoa & McDonald, 2020). The use of arts and humanities-based teaching methodologies for effectively fostering healthcare students' uncertainty tolerance is gaining momentum in medical education with a systemic review of 49 separate articles finding that arts-based pedagogy challenges concrete thinking, fosters reflection and improves uncertainty tolerance (Haidet et al., 2016). Furthermore, a recent scoping review found that arts-based teaching was repeatedly linked to helping healthcare students engage with uncertainty (Moffett et al., 2021). This study also concluded that a large gap remains in the understanding of specific teaching practices impacting learner uncertainty tolerance, suggesting that the solution may be research focusing on "cross-cultural studies" (i.e., outside healthcare education) to help address this gap.

Therefore, the aim of this research was to explore, in greater detail, HASS teaching practices moderating learner uncertainty tolerance in an effort to develop an uncertainty tolerance pedagogical framework for application to anatomy and healthcare education. In addition, this research served to build upon the previously identified natural uncertainties present in the anatomy learning environment (Stephens et al., 2021) and learn from HASS academic teaching practices of successful learner uncertainty tolerance development, particularly in relation to healthcare curriculum (DeForge & Sobal, 1989; Haidet et al., 2016; Gowda et al., 2018; Moffett et al., 2021).

A 2014 Australian University sector review of HASS disciplines found that these degrees make up the largest component of the university system (~65% of all undergraduate and postgraduate student enrollments), and that student satisfaction and job placements remain high (Turner & Brass, 2014). As healthcare education in some Australian universities remains undergraduate entry, these students often have little exposure to HASS education prior to their healthcare professional degree. Based on this collective evidence, this study sought to purposively explore Australian HASS educators' perspective of uncertainty tolerance teaching practices.

Through semi-structured focus groups and interviews, and purposive sampling, this study explored the following research questions: (1) What teaching practices do HASS academics' perceive as impacting learners' uncertainty tolerance, and (2) How do HASS academics execute these teaching practices? From this, recommendations are made for anatomy educators interested in exploring and fostering learners' uncertainty tolerance development in their own learning environments.

MATERIALS AND METHODS

Site and participants selection

The Faculty of Medicine, Nursing and Health Sciences within Monash University teaches ~16,680 students per year as part of the health professions degrees including: Biomedical degrees, undergraduate and graduate entry medicine, nursing, paramedicine, physiotherapy, psychology, and nutrition, with HASS academics contributing to the healthcare humanities components of these degrees (details below). To explore HASS academics' teaching practices that foster learner uncertainty tolerance, the research team purposefully sampled HASS educators who deliberately designed and delivered teaching to foster students' uncertainty tolerance at an Australian University. Additional to email invitations, snowball sampling facilitated the identification of appropriate educators. A total of 14 HASS educators across two campuses from five different faculties (ten teaching areas), agreed to participate in face-to-face focus groups or interviews over two months in 2019. Although participants were from HASS faculties, seven participants taught students across both HASS and STEMM (science, technology, engineering and mathematics, medicine) degrees (all participants in focus group (F G-1), one participant in focus group two and three). Together, the academics' varied disciplines and faculties, along with purposeful sampling of HASS educators, helped achieve information power (Malterud et al., 2016). To be included in the study, participants' teaching area (not necessarily related to their faculty) needed to be related to the Australian definition of HASS fields of research and education. These fields include: Architecture and Building,

Education, Management and Commerce, Society and Culture, and Creative Arts (Turner & Brass, 2014).

Data collection

All participants completed a demographic survey (see Table 1), with 56% of participants self-reporting female gender, and no representation from gender diverse participants.

The survey was followed by audio-recorded, semi-structured interview (four total) or focus group discussions (three total). Authors were facilitators (M.D.L., G.B., A.Z.).

The semi-structured protocol for both the focus groups and interviews were the same. The difference between these two data collection strategies were related to participant characteristics. Larger focus groups (FG-1) consisted of academics who taught into the same degree, and thus depth of discussion was based on shared context fostering interactive discussion (Davidson, et al., 2013; Ng et al., 2018), whereas smaller focus groups taught into different degrees, and the smaller participant number enhanced depth of data from these diverse experiences (Davidson, et al., 2013). Finally, those engaging in interviews enhanced further depth of discussion of the research topic (DiCicco-Bloom & Crabtree, 2006). Prior to commencement, participants were read the uncertainty tolerance definition (see introduction) and asked how they (within the classroom) prepare students for managing uncertainty. Semi-structured questions were designed to focus on eliciting discussion related to the domains of the uncertainty tolerance model (Hillen et al., 2017). Herein, questions explored how educators introduce, teach, integrate and foster uncertainty tolerance across units, courses and/or curriculum, and included questions focused on classroom stimuli, moderators and educators' perceptions of their students' classroom responses. Finally, participants were asked about what support academics need to consider including when implementing uncertainty tolerance teaching practices.

Team reflexivity

Prior to data analysis, all authors participated in a team reflexive exercise to improve team communication, function and research rigor (Barry et al., 1999). The team shared experiences and interest in the uncertainty tolerance topic, and this collectively drove the teams' research focus. The team were involved with teaching, though their learner population was diverse (undergraduate, graduate and professional learner populations). The research team had a variety of methodological research experiences and worldviews ranging from positivistic and quantitative, to interpretivism and extensive qualitative experiences. All team members, however, were positively oriented toward qualitative research for exploring the uncertainty tolerance construct in this HASS context.

Data analysis

Discussions were analyzed using an abductive approach (Lingard, 2015) with the uncertainty tolerance model as the theoretical lens (Hillen et al., 2017) and framework analysis as the methodology (Ritchie & Spencer, 2002). Framework analysis consists of five phases: (1) familiarization; (2) thematic framework identification; (3)

TABLE 1 Participant demographics

Focus group	*N*	Gender	Faculty	Teaching areas	Roles/Levels	Minutes
FG-1	5	3 F, 2 M	FMNHS; BUSSECO	Sustainability; HR	B	72
FG-2	2	1 F, 1 M	Faculty of Arts	Global studies, Sustainability	B & C	78
FG-3	3	2 F, 1 M	Faculty of Arts	Bioethics, Sociology, BUSSECO	B, C, D	71
Interview	***N***	**Gender**	**Faculty**	**Teaching areas**	**Roles/Levels**	**Minutes**
I-1	1	F	Faculty of Arts	Geography	C	55
I-2	1	F	Faculty of Arts	Criminology	B	40
I-3	1	F	Faculty of Education	Community development and partnership in education	D	25
I-4	1	M	Faculty of Education	Primary and secondary health and physical education	C	45
Totals						
I + FG	**Participants**	**Gender**	**Faculties**	**Teaching Areas**	**Roles**	**Minutes**
7	14	9 F, 5 M	4	11	B 4, C 4, D 2	386

Note: This table outlines participant demographics including self-identified gender, faculty association, teaching area, and academic level.
Abbreviations: BUSSECO, Faculty of Business and Economics; F, Female; FG, focus group; FMNHS, Faculty of Medicine, Nursing, and Health Sciences; HR, Human Resources; I, Interview; Level B, Lecturer; Level C, Senior Lecturer; Level D, Associate Professor; M, Male.

indexing; (4) charting; and (5) mapping and interpretation. Audio files were uploaded to Otter transcription tool (Otter.ai, Los Altos, CA), and facilitators (M.D.L., G.B., A.Z.) listened to and edited transcriptions in this platform (Phase 1, Familiarization). Familiarization was further enhanced with team (M.D.L., G.B., A.Z.) discussions about broad areas of alignment with, or extension of, the uncertainty tolerance model (Hillen et al., 2017). Later, A.G.V. read discussion files several times over to gain a broad understanding of themes. Phase 2 was led by M.D.L. and A.G.V., whereby the data were coded (led by A.G.V.) and regularly discussed between A.G.V., G.B., and M.D.L. until a final codebook, inclusive of definition and quotes, was reached. A qualitative data analysis software, NVivo 12 (QSR International, Melbourne, Australia) was utilized for data management. Code associations (i.e., when one distinct code occurred in concurrence with another distinct code but were interrelated within the participant's narrative) were identified in Phases 3 and 4. Once all interviews were completely coded, matrix maps were constructed to evaluate two-way stimulus-response associations/pathways. To explore more complex pathways/associations of three or more (including positive/negative sentiment), project maps were later constructed (Phase 5).

RESULTS

Across the focus groups and interviews, 386 min of data were analyzed (Table 1) resulting in a robust and in-depth coding hierarchy (Supplementary Material Appendices 1–3). From this, it was discovered that the participants conceptualized healthcare education-related uncertainty in different ways. Educators appeared to define uncertainty as either complexity or unknowns, but not synonymously:

> I think, in the way I've been teaching it, ambiguity is not necessarily associated with complexity, because you can have a simple situation that is still ambiguous. For example, I may work very hard on my essay, but I still don't know what I'm going to get … the standard is different. So, when students submit their first assignment, their first essay, they're really anxious because they don't know how good their best is. So, there's no great complexity involved in that. There's just uncertainty. (FG-2, Global Studies)

Other participants described learner uncertainty as "blind-spots" and/or "bias", and thus appeared to be conceptualizing uncertainty both on what it is, and on what it is not:

> You know what you know, but then you don't know what you don't know. There's the blank spots in the blind spot; The blind spots that you know, we don't really want to pay much attention to. We know that if we don't pay any attention [to] 'the blind spots', 'we' don't even know that we don't even know it. And that kind of adds to the complexity of complexity, because complexity says that I can describe a system that's complex, but I still know all the elements and their main interactions. But the blind spots are when we don't even know elements that are there. We don't even know what's there. So, there's kind of layers of uncertainty, there's a cascade of chasms between what we think we know and what we actually live in. (FG-1, Sustainability)

Extending these broad conceptualizations of uncertainty, more detailed descriptions of classroom teaching themes relating to the uncertainty tolerance model components are described in the following sections.

Stimuli

Identified uncertainty stimuli spanned four broad teaching strategies (Supplementary Material Appendix 1): (1) Questioning student pre-conceptions, (2) Learning transfer to different contexts, (3) Purposeful design and implementation of authentic "grey" case scenarios, and (4) Content presented from multi-disciplinary/faceted perspective. Inculcated across all stimulus-related participant discussion was that these teaching practices are both purposeful and integrated at a broad curricular level (across the entire semester and/or year and/or degree) as opposed to being one-off, *ad-hoc* teaching practice.

Stimulus—Questioning student pre-conceptions

Educators described designing learning activities and/or assignments which purposefully challenged learner views, beliefs, and assumptions. Here, an educator describes challenging students to rethink what a chair represents:

> … we just use the chair…, we say 'okay, this is a chair. So, we have socially determined this is an article for sitting on. However, someone else could, you know, come into this, and it could be a cupboard … and you can see their minds being blown. (FG-3, Sustainability)

Stimulus—Learning transfer to different contexts

For some educators, classroom practices encouraging "multiple tools for multiple contexts" (I-4, Primary and secondary health and physical education) stimulated uncertainty by challenging learners to transfer knowledge between contexts:

> … students need to transpose the analytical skills that they develop when they read a text to real life. So, in

> the same way that they read a scene, they must learn how to read a situation. So, they start … with short stories, then they move on to film, and then they move on to a real-life scenario. (FG-2, Global Studies)

Stimulus—Purposeful design and implementation of authentic "grey" cases/scenarios

Educators also described deliberate presentations of ambiguous or complex scenarios (i.e., grey cases) wherein they challenge students to consider the "grey" areas of discipline content. Examples of these included future-focused, complex, and/or ambiguous workplace scenarios:

> But then you might say, 'but what about if we move to this particular model of powering cities? What does that do in terms of the economy?' And students will say, 'but, you know, it's really good for the environment.' I said 'yeah, but what happens to those people who lose their jobs because the type of power in cities changes?' And so, they have to actually learn to live with a whole range of factors, and not just consider the right answer, because the right answer is we need to do something about climate change. But there's complexities within those right answers … that can be very challenging. (FG-3, Business and Economics)

Stimulus—Content presented from multi-disciplinary/faceted perspectives

Educators' described encouraging learners to expand their worldviews by presenting a variety of viewpoints about a given topic.

> They look at Indigeneity, radicalization and genocide … So, you'll have an economist talking about genocide, a social scientist talking about genocide, a medical doctor talking about radicalization … because when we're talking about global studies and addressing global issues, it can't be done from a single discipline. So, this allows them to see that these problems can be approached from, you know, a myriad of perspectives. (FG-2, Global Studies)

Moderators

Moderators, within the higher education context, refer to factors impacting learner responses to educational uncertainty stimuli, including "situational characteristics as well as cultural and social factors" (Hillen et al., 2017). Within this current study, three moderator themes were identified (Supplementary Material Appendix 2; Table 2): (1) Knowledge and experience relative to uncertainty; (2) Educator approach; and (3) Learners' personal attributes. Each moderator theme had multiple subthemes and codes described below.

Moderator—Knowledge and experience relative to uncertainty

The interrelated nature of learners' prior knowledge and prior exposure (or lack thereof) to uncertainty stimuli were described as: (1) Subject mastery and/or experiences (high and low) and (2) Discipline background. High mastery included learners with prior uncertainty experiences, often through experiential learning opportunities, and/or previously acquired discipline knowledge. Both types of prior uncertainty experience were perceived as fostering learner uncertainty tolerance. Low mastery predominantly related to educators describing learners new to university or new to the discipline content. Participants discussed investing effort in scaffolding uncertainty stimulus exposure by developing ways to support "low mastery" learners', as these students were perceived as struggling with uncertainty. (see related quotes in Table 2).

The moderator of *discipline background* (Table 2) refers to educator perception of learner's worldview, as it relates to their knowledge (not as an individual characteristic). A subjective worldview was predominantly linked to HASS students, while an objective worldview related to STEMM students. There were also some educators that acknowledged a spectrum of learner worldviews, but noted that the location of learners on this spectrum appeared dependent on their study field, which was described below as discipline tension:

> There's a big range in terms of how students respond, because I don't think there's necessarily as clear a tradition of how you would approach a problem solving or a research question [in sustainability] as there would be in the physical sciences, or what a lawyer would do. You know, with lawyers, they've been trained in a very specific way of attacking of a problem, and physical scientists another way, whereas there's a few degrees that kind of sit in a space that's a bit more flexible. And then there's a few that are sitting in the space of just like, 'everything is contested', and let's just have lots of discourse and arguments, and they're the ones who can often thrive in the context of discussing worldviews and uncertainty, but maybe be less useful on the sharp end of sustainability in terms of what do you do. (FG-2, Sustainability)

Moderator—Educator approach

The second identified moderator encompassed the educators' teaching approaches and practices ranging from practical classroom methods to purposeful pedagogical design. Subthemes included: (1)

TABLE 2 Uncertainty tolerance moderators identified

Moderator Theme: Knowledge and Experience Relative to Uncertainty	
Subtheme	Exemplar quote
High subject mastery	"… prior experience and prior knowledge and they've got, you know, working environment, large family chaos disorder around them. And they've got some tools to cope. Whereas, I guess fewer experiences [yield a] narrow set of tools to draw upon, poorer role models … you're probably going to struggle with that." (I-4, Primary and secondary health and physical education)
Low Subject mastery	"… I think we need to go down to the steps that students can take, and things they can latch on, particularly at an introductory level when students struggle not only with ambiguity itself, but that affective element of ambiguity that stresses them." (FG-2, Sustainability)
Discipline background	"The big difference that I see with our STEMM versus our HASS students is that the STEMM want to be sequential, you do 'A', then you do 'B', then you do 'C' and we have to actually teach them iterative, iterative practice." (FG-2, Sustainability)
Moderator Theme: Educator Approach	
Subtheme	Exemplar quote
Challenging student assumptions/ worldviews	"And then the students were literally thrown into the deep end, they got to [another country], they had to produce these really detailed reports with very little academic guidance. And they were in this foreign country they had never, most of them had not yet, all of them had not been … before. And then they are going to rural areas … So, there was a lot of ambiguity and I think what was really stand out for me was the students who really thrived in that, took advantage of the ambiguity, they relished it. They were probably, like, they looked for adventure, I think that would be a good way to put it. They were open to new experiences. They were resourceful." (FG-3, BUSSECO)
Uncertainty management tools	"So creating the opportunity for self-reflection as well, is really important. That can happen automatically in that work, work-integrated learning space because they have to often reflect on that experience. Then, in other units that mean that could look like stopping writing what I call 'One Minute Papers' where they just write a response to themselves, like a memo to themselves reflecting on what we talked about." (FG-3, Sociology)
Open pedagogical Instruction	"But I think part of that stems from the fact that there was no grading attached to what we were doing. So, the students actually felt that they had the freedom to plunge into the experience, and, and have a deep learning experience at a human level. Which is the silliest thing, because you can't do that when you're marking." (FG-2, Global Studies) "we spent a lot of time … we did write out instructions, but we just gave them a lot, we gave them more choice than we've ever given them before. … So, they could do a podcast, they could do a poster, they could do an online news article, look, they could do a video, whatever. And we just reassured them." (FG-3, Sociology)
Closed pedagogical instruction	"I think students are incurring a lot of suffering because of the affective component of 'Oh, my God, I don't understand. I don't know what's happening.' So, when we give them straightforward steps to deal with this, and I think that's where analysis and collating information comes into play … I am in putting, I guess, boundaries around the uncertainty and ambiguity for students." (FG-2, Sustainability)
Exposure to diversity through teamwork and collaboration	"… an integral part of it [bachelor of Global Studies] is diversity in teams. And we start addressing that seriously from week one or two. I get a report from the faculty that says whether they're doing a single degree or a double degree, what the double degrees is in. We ask them whether they speak a second language. We try to have, to the extent that it's possible because we have an 80% female cohort, a balance of gender. So, we do disciplinary background, whether they're doing a double degree or not, a second language, parents from … who have a different cultural background to that of a typical Australian background, whatever that may be, and we'd normally have a discussion on that. And with bringing those factors into consideration, we try to make the teams as diverse as possible, to expose students to those different point of views from first semester." (FG-2, Global Studies)
Exposure to unease and/or discomfort	"And so we start with over the course of the first few weeks, I try and physicalize a lot of the differences that appear in the room by forcing the students that get up and move around and orient themselves based on things like: Geographically where they're from. Conceptually, how much do they identify with certain statements, they do worldview quizzes that are structured based on research frameworks, and then position themselves around the classroom. They distribute themselves by discipline. And I asked them to do things like how you need to, you need to as a class, organize yourself by how far away your disciplines are, and they have to negotiate and understand that." (FG-1, Sustainability)
Intellectual streaking	"So, I think modelling is important as well, like the perfect tutor or the perfect lecturer or the perfect … [pause] … doesn't necessarily help. And so, showcasing how we have gone through the process I think is relevant … I'll shoot videos from a class just off the fly and leave all the errors in it and not edited and make it look nice and then go off. Sorry, stuffed that up. So, you can kind of be a bit more real. Yeah. And I think the students respond to that" (I-4, Primary and secondary health and physical education)

TABLE 2 (Continued)

Moderator Theme: Knowledge and Experience Relative to Uncertainty	
Intellectual Candour	"So that is often telling stories of how like from my background, I encountered this particular piece of information, which was different, I struggle with it and interpreted it … So, this kind of being quite explicit about my own experiences and also about where the uncertainties and ambiguity and things like, tasks are, and telling them that they are purposeful …" (FG-1, Sustainability)
Moderator Theme: Learner Personal Attributes	
Subtheme	**Exemplar quote**
Extrinsically merit-minded	"I think cognitively, yes, there is resistance in just this need for an answer and, and 'tell me what to do' and the high achieving students will ponder and think about it. I think, the climate we're in now, in terms of the students just are such busy lives and they literally just want to come and 'this is how it is', and 'this is how you should respond', and 'these are the skills you need'. 'So, learn these and you're going to be fine'… So, uh, yeah, I think students find it very challenging. It pushes them out of their comfort zone." (I-3, Community development and partnership in education)
Humility	"… so, we talk about decolonizing knowledge. And that requires a great deal of humility, I think, particularly coming and working within a Western academe. So respecting Indigenous knowledge, for example, dismantling ways in which we were taught, you know, dismantling ways of knowing and acknowledging these other knowledge systems …' To 'Oh, we should actually be listening to what people need, and not telling them what people need.'" (FG-3, BUSSECO)
Cognitive flexibility	"Flexibility is another. Like, there's just this sense of 'Sure. It could be that right? Yeah, I can see that.' And there's a certain sense of ease that comes with that. … I often see it with students who have taken a year to travel across India, things like that. They're like, 'people do things differently in different parts of the world.' And they get it. So, there's first of all, a cognitive flexibility that allows them to see, 'I get this, I understand how they're doing ways of doing things so we can approach things differently. And this is not directly challenging my identity.'" (FG-2, Sustainability)

Note: Uncertainty tolerance moderator themes, subthemes and example quotes identified in the data are included in this table. Codes are not included in the table.

Challenging student assumptions and worldviews; (2) Uncertainty management tools; (3) Pedagogical Instruction (open or closed) through scaffolding uncertainty; (4) Exposure to diversity through teamwork and collaboration; (5) Exposure to unease and/or discomfort; and (6) Intellectual streaking or candor, and are defined further below.

Learners' assumptions and worldviews were challenged by embedding uncertainty within the curriculum, including cultural immersion in global overseas programs or educators intentionally designing experiential learning exposures to "help them experience it and learn to live with it" (FG-3, Sociology).

Many participants discussed weaving a variety of uncertainty management tools into the curriculum to foster learners' uncertainty tolerance (Table 2). While some participants did not provide explicit details about these tools (categorized as *general tools*), others discussed specific approaches including: (1) Self-reflection; (2) Strategies for managing risk and accepting error; and (3) Providing uncertainty dress-rehearsals. Self-reflection, in particular was a dominant tool described in the data (Table 2).

Educators also described moderating uncertainty tolerance through *open* and *closed pedagogy*. Open pedagogical instruction referred to less prescriptive guidelines which were often not attached to formal assessment, or through providing choice for assessed components. *Closed pedagogy* included educators' descriptions of 'bounding' the classroom uncertainty through calculated steps, especially for students with no or limited uncertainty experiences (e.g., *low subject mastery*).

Exposure to diversity through teamwork and collaboration was another educational moderator used to expose learners to alternate ways of thinking and doing, by taking deliberate steps to assemble teams from diverse cultural, socioeconomic, gender (etc.) backgrounds.

Moderating learner uncertainty tolerance development was also seen in educators' setting clear expectations that discomfort and/or unease is implicit to deep learning, helping learners become aware, and explore 'sitting with', this uneasiness. In this way, the theme of exposure to unease and discomfort differed from the theme of uncertainty management tools because the former was not a tool, but a learned practice:

> You have to set the expectations that these WILL be uncomfortable, you WILL feel very … [pause] … it could feel painful. But that [is the] very point of learning for you. (FG-2, Sustainability)

Intellectual streaking and/or candor focuses on the educator embracing their own vulnerabilities around uncertainty, and being transparent in order to help normalize the learner's uncertainty experiences (Bearman & Molloy, 2017; Molloy & Bearman, 2019). *Intellectual streaking* included examples where the educator was "fully exposed" in these vulnerabilities, whereas *intellectual candor* is relevant to the learners' assigned tasks, and thus becomes a bounded exposure of educator vulnerability.

Moderator-learners' personal attributes

Educators perceived that learners' personal attributes influenced learner uncertainty tolerance, and included subthemes: (1) Extrinsically merit-minded; (2) humility; and (3) cognitive flexibility. The moderator of *extrinsically merit-minded* described learners who

were hyper-focused on assessment and/or class performance, and as a consequence appeared to struggle developing uncertainty tolerance. This is contrasted with *learner humility*, for example, permitting space for "others to be right," appeared to positively moderate, learners' responses to educational uncertainty. This was mirrored with learners described as *cognitively* flexible, as they were able to "focus on the right things at the right time" (I-4, Primary and secondary health and physical education).

Those described as cognitively inflexible were perceived as less tolerant of educational uncertainty. In this study, HASS educators typically linked this subtheme with students in STEMM disciplines:

> it's amazing how many science students I've worked with think, if you do a statistical test and its significant, then that's the truth. They might have asked the silliest question that doesn't make biological sense in ANY way. But if they get a positive stat … (FG-2, Sustainability)

Participants described their perceptions of learners' responses to educational uncertainty, in the context of described moderators. Perceived learner responses, and the links between moderators and responses are described in more detail below.

Responses

Across the data, educators' perceptions of their students' cognitive, emotional, and behavioral responses were discussed (Table 3, Supplementary Material Appendix 3).

Within each domain, participants' perceptions of learner responses represented a spectrum from positive (+) to negative (-). Described positive cognitive responses included: *understanding/accepting uncertainty*; *receptiveness*; and *confidence* in managing uncertainty. These described learner responses appeared to result from longitudinal and developmental educational processes wherein learners were continually exposed to uncertainty, either through real-world experiences or classroom teaching practices. This progressive approach in developing learner uncertainty tolerance was often described as transformational, with responses indicating permanent changes to learner's mindset. In contrast, the negative cognitive response included being resistant and avoiding uncertainty and was predominantly linked to novice students starting university.

Behaviorally, participant responses described predominately negative perceptions of learner responses, including themes such as *non- or avoidant participation* or *entitled information seeking*, and often were associated with perceptions of learners' negative emotional response (e.g., *feelings of stress*, *anxiety*, or *feeling overwhelmed*). While academics' perceptions of learner responses to uncertain stimuli were usually situated at one end of the spectrum (negative or positive), *vulnerability* (an emotional response), had an indeterminate valency.

Pastoral care

A theme identified across the dataset was the perceived importance of *pastoral care* when executing uncertainty tolerance teaching practices. This theme referred to emotional support, leadership, and mentorship required when engaging uncertainty tolerance teaching practices. Participants expressed the need to support students with *low subject mastery* and/or students from disciplines typically linked to *objective worldviews* (e.g., STEMM) illustrated by the quote below drawing upon a boat metaphor:

But you approach a kid who's doing science and has no notion of this with that. And it's just too unmooring. And the point is not to unmoor them, but to give them a sense that from this unmooring, they can find, ah, they can find direction and that to empower them, to understand that there is a process of unmooring, of course, but from that comes direction. And from self-reflection and cogitation, comes a new understanding. And I didn't understand that at the beginning when I started teaching. I think I just threw them into the deep end of the pool, and many of them tanked. … So that's been a learning curve for me. Understanding that not everyone approaches ambiguity with the ease that certain disciplines do. (FG-2, Global Studies)

Stimuli, moderator and response interactions

The depth and richness of data allowed exploration and analysis of linkages between, and across, different parts of the uncertainty tolerance conceptual model (Hillen et al., 2017). Herein this study identified educators' perceptions of how certain educational uncertainty stimuli were perceived by learners, and how different moderators were perceived as impacting on learner responses. Educator-sourced moderators are ones described as originated by or from the teacher (e.g., pedagogy, teaching practices), while learner-sourced moderators are student-derived (e.g., traits or worldviews). Figure 1 illustrates "grey cases" as an exemplar of uncertainty tolerance model interaction, as the moderator interactions herein were complex and nuanced.

Interactions: Grey case stimulus

The uncertainty educational stimulus of "grey cases" were perceived as eliciting a variety of learner responses, depending on the classroom moderators at play. If students had low subject knowledge mastery, and a subjective worldview (moderators), learners were perceived as having resistance (negative cognitive response) and being disengaged (negative behavioral response). However, if learners were perceived as having a subjective worldview (moderator), regardless of discipline knowledge level, educators linked this to entitled information seeking (negative behavioral response). Similarly, if grey cases were introduced, and students were reported as cognitively inflexible, then learners appeared to respond with negative emotional appraisals (stress, anxiety and feeling overwhelmed).

TABLE 3 Learner response themes

Response domain	Code	Definition	Example quote
Cognitive	Understanding/Accepting Uncertainty (+)	Learner awareness and/or acknowledgement of uncertainty being implicit in career/discipline	"And I'll just add that what dealing with uncertainty and ambiguity looks like for students does, in my experience, differ between undergrads and post graduates. And that could be contextual, because the latter group has a stronger understanding of the natural uncertainty and ambiguity in the world. Where's the former may not yet be at that stage?" (FG-2, Sustainability)
	Receptiveness (+)	Students openness to exploring and responding to uncertain pedagogy	"I teach, there is no one answer, there is no right answer. And I feel like once you get them to that stage, they're suddenly receptive." (FG-2, Sustainability)
	Confidence in ability to manage uncertainty (+)	Learners acquiring self-assurance in their ability to manage when presented with uncertainty stimuli	"And the sort of skills that I hoped that they would develop were compassion toward their own ability to deal with the distress of not having firm ground underneath their feet. But having the confidence to go ahead based on what they knew to practice what they knew in whatever field they were going in." (FG-1, Sustainability)
	Resisting/Avoiding Uncertainty (−)	Learners experiencing a cognitive struggle or confrontation in response to uncertainty	"There's pushback, and, and I think, intellectual I would associate, maybe I'm wrong, but I wouldn't associate intellectual and scholarly maturity with that ability to understand that there's subjectivity. And what I normally encounter with 17, 18-year olds for the first year is, this is the way of the world. 'What are you talking about? There's one way of doing things. It's the right way. It's the way that gets me the marks. It's the way that's gonna get me the job.'" (FG-2, Global Studies)
Behavioural	Non- or Avoidant- Participation (−)	Learners who physically disengage or just did enough of the assignment to 'complete it', minimizing their engagement with the uncertainty component of the educational task	"And so that, yeah, that it can be emotionally challenging, and some will, some might kind of shut off to it or avoid it use a lot of avoidance strategies, to not have to put themselves through that uncertainty." (I-2, Criminology)
	Compulsive Information Seeking (−)	Learners who perpetually pursue knowledge in a manner that appears neurotic, irrational, and detrimentally driven	"… that anxiety … It's often translated into a lot of questions, a lot of consulting with tutors, a lot of double checking. One of the things that I noticed with first year students is they'll double check almost everything. And I started to become rather frustrated with the fact that the double checking they were doing was so banal. So, you know, we'd get them to write an essay. And they'd be double checking where you wanted the page numbers on the page … we had everything written out in such strict instructions that they thought, if it's not on the instructions, then I need to double check before I put my essay in in case I get in trouble. My Moodle forums were full of 'where do you want the page numbers? Do you want them at the bottom left hand corner? The bottom right hand corner, or the bottom centre? … It's almost like they've become so used to being told what to do, that I just started to notice these signs … I just thought this is excruciating, cause I'm answering the same questions, but they're not asking questions about the content, or 'should I write this or should I right that' they're not engaging the content, they're engaging with the format." (FG-3, Sociology)

(Continues)

TABLE 3 (Continued)

Response domain	Code	Definition	Example quote
Emotional	Stress and Anxiety (−)	Learners exhibiting pressure, tension and worry in the face of uncertainty	"I get overwhelming sense of, you know, your anxiety, stress response goes up fight or flight, you know, that kind of panic." (I-2, Criminology)
	Overwhelmed (−)	Learners described as feeling overcome in the face of uncertainty	"And I think particularly sometimes, at the start of their degree, students can get overwhelmed with how much they don't know …" (I-4, Primary and secondary health and physical education)
	Vulnerable (+/−)	Learners exhibiting openness and accepting, displaying signs of exposure in response to uncertainty	"And I think there is, there is an affective, an emotional component that is really important. And that, at best, can be approached through self-reflection. I mean … there's an element of vulnerability and the sense that it's not scholarly to discuss your emotions given a willingness, self-reflection. But I think it's, it's a crucial part of the process. And it's one that I don't know how to assess properly." (FG-2, Global Studies)

Note: Themes identified through participant discussion of perceptions of student's responses to uncertainty stimuli within the educational context. Included are the definitions and example quotes for each theme.

On the positive end, when educators engaged in intellectual candor (moderator) or designed their teaching approach to allow for purposeful learner exposure to discomfort (moderator), students appeared to respond with confidence to manage this uncertainty (positive cognitive response). If learners had an objective worldview, but educators challenged student assumptions through multi-disciplinary educational environments (both moderators), students appeared to be accepting of this uncertainty (positive cognitive response). If, on the other hand, students had a subjective worldview (moderator) and educators designed learning activities to include purposeful exposure to uncertainty, multi-disciplinary approaches, and helped students manage risk and accept error (moderators)—then students accepted uncertainty (cognitive positive response) arising from grey cases.

Interactions: Questioning student pre-conceptions stimulus

When educators questioned student pre-conceptions (stimulus), the learner's responses were percieved as mostly positive. Moderators that appeared to temper this uncertainty stimulus positively included: student attributes of humility and educator approaches of exposure to discomfort or exposing students to strategies for managing risk and/or accepting error. Conversely, this same stimulus moderator by the educator engaging intellectual candor (moderator), with students' who were perceived as cognitive inflexible (moderator), appeared to result in negative emotional responses of anxiety.

Interactions: Transferring learning to new contexts stimulus

Transferring learning to new contexts (uncertainty stimulus) included a wide variety of moderator interactions. If educators used open pedagogical approaches (moderator) with students who held objective worldviews (moderator) and were relatively cognitively inflexible (moderator), learners were described as responding with resistance to uncertainty (negative cognitive response). However, if educators moderated the classroom by teaching students' general tools to manage uncertainty (moderator), using this same stimulus, learners responded with a positive cognitive response of receptiveness.

Interactions: Multidisciplinary, faceted perspectives stimulus

All moderators associated with pedagogical uncertainty stimulus of multidisciplinary, faceted perspectives appeared to modulate learner responses toward the positive end of the appraisal and response spectrum (i.e., more tolerant of uncertainty). If educators described providing uncertainty dress rehearsals alongside intellectual candor, or by challenging student assumptions in a multidisciplinary environment while scaffolding uncertainty (all moderators) with this uncertainty stimulus, learners appeared to positively respond with receptiveness (cognitive response). If educators introduced general tools for managing uncertainty, and students were cognitively flexible (both moderators)—students appeared to accept uncertainty (positive cognitive response).

Interactions: Moderators and learner responses

Participant discourse did not always include an uncertainty stimulus. However, participants often described moderators relating to perceived learner responses allowing for exploration of linkages between moderators and responses (Table 4). Some moderators appeared to work in concert, influencing students' responses to uncertainty stimuli.

DISCUSSION

This research serves to advance understandings of how teaching practices can purposefully foster learner uncertainty tolerance, particularly in foundational anatomy education where there is an already identified implicit link with uncertainty and uncertainty tolerance (Willan & Humpherson, 1999; Stephens et al., 2021; Wheble & Channon, 2021; Cullinane & Barry, 2022). The results of this study suggest that HASS teaching practices designed to foster learner uncertainty tolerance broadly align with the prevailing uncertainty tolerance model (Hillen et al., 2017), with identified themes mapping to each conceptual model domain (stimuli, moderators, and responses), suggesting transferability of HASS uncertainty tolerance teaching practices (Firestone, 1993) to other educational contexts.

Given that uncertainty is intrinsic to healthcare, evidenced in part by the Covid-19 pandemic where uncertainties stemmed from the biomedical nature of the virus, and the psychosocial aspects of healthcare including public health communication (Finset et al., 2020), care of patients (Young et al., 2020; Lin et al., 2020) and healthcare provider well-being (Rolland, 2020; Valeras, 2020; Zerbini et al., 2020; Di Trani et al., 2021) helping students develop uncertainty tolerance becomes increasingly important. This study suggests that anatomy educators can potentially foster uncertainty tolerance early in the healthcare education pathway by purposefully designing curriculum that stimulates uncertainty (e.g., grey cases) and can also then help students learn to manage this classroom uncertainty by selectively timing identified moderators (e.g., reflective practice) to support learners in their unique contexts (e.g., novice vs. experienced learners).

Uncertainty tolerance remains a valuable attribute in everyday healthcare practice. There is growing evidence that doctors with lower uncertainty tolerance are more likely to over-order tests (Rao & Levin, 2012), increase healthcare costs (Bhise et al., 2018), have dogmatic tendencies (Iannello et al., 2017; Geller et al., 2021), are more likely to suffer from psychological distress (Hancock & Mattick, 2020), and contribute to healthcare disparities (Balsa et al., 2003). Those with higher uncertainty tolerance appear to be more open to diversity, have improved attitudes toward the underserved (Kvale et al., 1999; Wayne et al., 2011), and engage in patient-centered care (Portnoy et al., 2013; Berger et al., 2017). In this way, designing healthcare education which serves to longitudinally develop learner uncertainty tolerance is both timely and relevant, and this research provides practical recommendations which serve to accomplish this (described in more detail below).

Stimuli

Data analysis identified key pedagogical stimuli which can be applied across healthcare classrooms, as many of these stimuli were generic (not explicitly tied to HASS content) in nature, and have been implemented in healthcare education previously. For example, integrating *grey cases* (e.g., complex discipline-focused case problem solving) is shown to provide uncertainty tolerance practice opportunities in multiple disciplines including: clinical anatomy (Stephens et al., 2021), healthcare education (Khatri et al., 2021), business (Rippin et al., 2002), and mathematics (Voskoglou, 2011)—suggesting transferability of this theme (grey cases) from HASS education to education more broadly. Efforts toward inclusion of identified uncertainty stimuli into disciplines such as anatomy may be particularly relevant to address the predominance of reported lower uncertainty tolerance of students starting medical school (Strout et al., 2018; Geller et al., 2021), and given that anatomy is often a cornerstone of healthcare curricula (Sugand et al., 2010).

Anatomy educators may work toward stimulating uncertainty by engaging *multifaceted points of view*. When teaching shoulder anatomy, for instance, anatomists could present the anatomical structures associated with shoulder anatomy and movement and invite a multi-discipline panel to discuss their diverse perspectives of shoulder anatomy. This panel could include: A general practitioner to discuss shoulder examination considerations, a surgeon who focuses on shoulder repair surgical approaches (including relevant anatomical variations), a physical therapist outlining shoulder rehabilitation strategies, a radiologist debating evaluation approaches when viewing medical imaging of the shoulder, and a patient who has lived experience of shoulder pain. This approach has already been shown to be of value to improving anatomical learning (Lazarus et al., 2014; Stott et al., 2016), and this study suggests that this same approach could prove useful in fostering learner uncertainty tolerance when purposefully designed to do so. Educators can harness existing anatomy education teaching practices to foster uncertainty tolerance development by expanding the focus of such panels from exclusively emphasizing relevant knowns (i.e., shoulder anatomy) toward an approach which includes discussing "unknowns" or points of contention between these diverse panel members. Results herein suggest that engaging this multi-disciplinary panel to not only cover the anatomy, but also review the points of ambiguity, will help students understand that while the shoulder anatomy knowledge is relatively stable—the relevancy, focus and application of shoulder anatomy is highly variable (i.e., uncertain and complex) in clinical practice.

Moderators

This research broadens the fields' understanding of the complexity of an individual learners' uncertainty tolerance, particularly around the concept of moderators. Prior to this study, educational moderators were predominately listed and described as independent, singular factors modulating uncertainty tolerance (Hillen et al., 2017; Strout et al., 2018). However, in this study, moderators originated from two sources, both the educator and the learner. Each moderator, and its source, interacted across the learning environment in numerous circumstances suggesting a complex interplay of educator and learner-sourced moderators which may, in turn, be impacting on students' responses to educational uncertainty stimuli. This

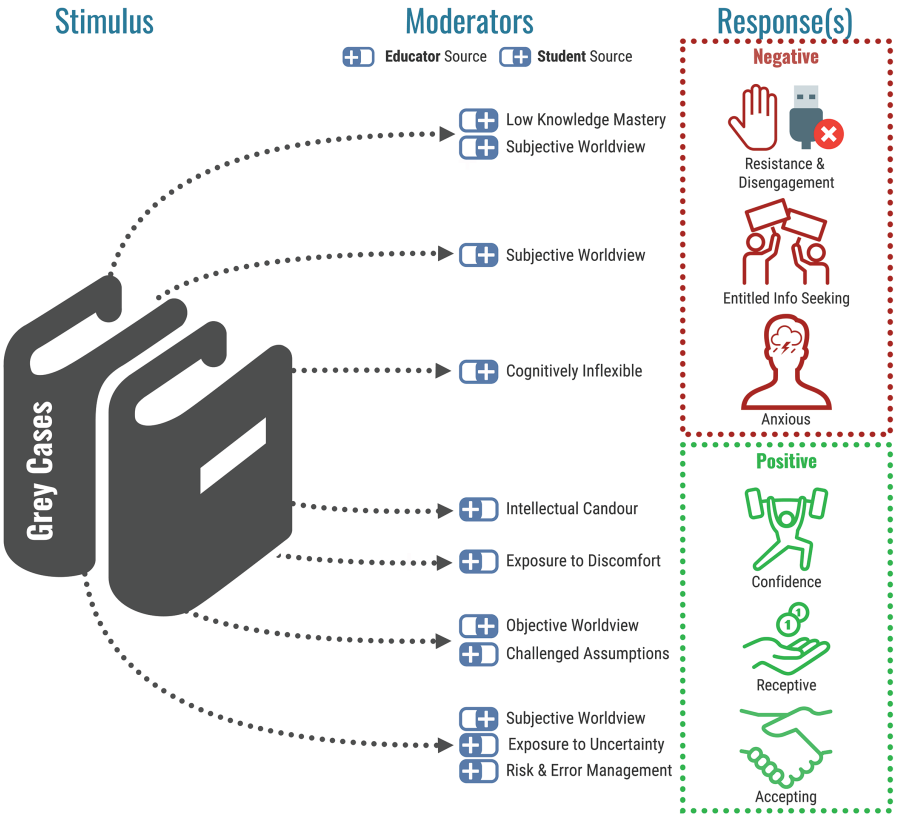

FIGURE 1 Educator perceptions of interactions across the uncertainty model in the classroom setting. using the uncertainty stimulus of "grey cases", our data suggest that different moderators (either derived from the educator or the learner) can result in changed learner responses. Some moderators modulate these responses negatively, others moderate these positively. Moderators, in some cases, appear to work in concert to impact these learner responses (lower half of figure)

interaction of moderators with each other could also explain why a systematic review of moderators such as age and learning stage had diverse impacts on uncertainty tolerance, with these moderators reported as negatively, positively, or neutral impacts on learner uncertainty tolerance (Strout et al., 2018). If moderators do, indeed, interact and work together to modulate learner uncertainty tolerance, then isolating the impacts of a single moderator (as many of the included studies attempted) may be challenging and lead to the observed inconsistent results.

Indeed, this current study analysis revealed a pattern of moderator interdependency (Figure 1). This pattern suggests that educators have agency and opportunities to manage learner uncertainty tolerance. The choices educators make will depend on the educational stimulus chosen, the learning outcomes planned, and the educators' desired learner response, as well as the consideration of learner-sourced moderators. Therefore, this study found educators are able to purposefully select educator sourced modifiable moderators (e.g., diverse teamwork, intellectual candor) to counteract more static learner-sourced ones (e.g., year level, discipline background) to develop the most effective curriculum to foster uncertainty tolerance in a given educational context. Educator awareness of the moderating factors 'at play' in their unique learning context allows for opportunities to be more responsive to learners' needs at a particular time in their learning journey (Figure 2).

In considering the anatomy learning environment, anatomists often teach first year medical students (Drake et al., 2009; Sugand et al., 2010), wherein students typically have a 'low subject mastery' of anatomy knowledge. This student-sourced moderator, based on study results, appears to influence learners' uncertainty tolerance towards 'less tolerant'. Armed with this knowledge, anatomists can build in educator-sourced moderators which counteract this negative moderator, by engaging uncertainty management tools such as formative self-reflection activities (educator-driven moderator). Reflective practice, in particular, is a moderator that appears to improve both medical students' (Nevalainen et al., 2010) and educators (Attard, 2008) uncertainty tolerance, further underscoring that findings in this study likely have broad application to multiple learner contexts.

Key to an educators' capacity to moderate learners' uncertainty tolerance, is an awareness of which uncertainty tolerance moderators are present in their classrooms. Anatomists, given the time they spend with students in the anatomy laboratories (Drake et al., 2009), are well placed to have a holistic knowledge of their learner population and classroom dynamics, reinforcing the anatomy learning environment as an ideal context for fostering learners' uncertainty tolerance early in the students' learning journey.

As described in this study, anatomy educators may consider stimulating learner uncertainty via "grey cases" or case-based studies which are a frequently used tool in the anatomy classroom, as well as other

TABLE 4 Interactions between moderators and learner responses

Moderator theme	Moderator code(s)	Response(s)	Valency
(L) Subject Mastery	(L) High Subject Mastery and (L) Cognitive flexible	Cognitive	+
	(L) High Subject Mastery (E) Intellectual Streaking	Cognitive	+
	(L) High Subject Mastery (E) Tool to deal with uncertainty	Cognitive	+
	(L) Low Subject Mastery and (E) Teach Self-Reflection	Cognitive	+
(L) Discipline Background	(L) Objective worldview	Cognitive Behavioural	+/−
	(L) Subjective worldview	Cognitive	+
(E) Challenging Student Assumptions	(E) Purposeful uncertainty exposure and (E) self-reflection	Cognitive	+
	(E) Multidisciplinary environment	Behavioural	+
	(E) Through purposeful uncertainty exposure and (E) Multidisciplinary environment	Cognitive	+
	(E) Purposeful uncertainty exposure and (S) Objective Worldview and (S) High Subject Mastery	Cognitive	+
	(E) Purposeful uncertainty exposure and Exposure to Unease	Emotional	−
(E) Tools for managing Uncertainty	(E) General Tools and (L) Learner Agency	Cognitive	+
	(E) Providing dress rehearsal	Cognitive	+
	(E) Self-Reflection	Cognitive	+
	(E) General Tools	Cognitive	+
(E) Pedagogical Instruction/Format	(E) Open Pedagogy	Behavioural Emotional	+/−
	(E) Scaffolding Uncertainty (Closed Pedagogy)	Cognitive Behavioural	+
	(E) Scaffolding Uncertainty (Closed Pedagogy) (E) Exposure to diversity via Teamwork	Behavioural	−
(E) Exposure to diversity via teamwork and collaboration	(E) Exposure to diversity through Teamwork	Cognitive Emotional	+/−
(E) Intellectual Streaking	N/A	Cognitive Emotional	+/−
(L) Personal Attributes	(L) Humility and (L) Cognitively Flexible	Cognitive	+
	(L) Merit Minded	Behavioural Cognitive	−
	(L) Cognitively Flexible	Cognitive	+

Note: This table summarizes trends identified (via matrix coding) between moderators and responses. Some of these codes originated from the educator (E), while others were reported as learner-centred (L) moderators. Coding identified perceptions of learner uncertainty response valency, with (+) indicating language associated with a positive valency, and (–) indicating negative valency according to the Hillen et al. (2017) uncertainty tolerance conceptual construct model . Some themes had different valence depending on the participant/context (+/–).

disciplines (Hutchings, 1993; Kim et al., 2006). If an educator chooses to use this approach to stimulate uncertainty in learners who have more objective worldviews (i.e., clinical anatomy students, based on study results), this study suggests that inclusion of an educator-sourced moderator (e.g., uncertainty moderating tool of managing risk and accepting error), may counteract learners' negative response(s) perceived when this moderator is left in isolation. While many of these educator-driven moderators are already shown as effective teaching strategies for either managing uncertainty in the anatomy learning environment (Rippin et al., 2002; Stephens et al., 2021), or for learning more generally (Gijbels et al., 2005; Baeten et al., 2013; McLean, 2016), this study illustrates that anatomy educators may have the power and agency to purposefully select a number of moderators at different points in the learning journey in order to direct learner responses to uncertainty stimuli positively, potentially preparing them for implicit uncertainties in their future healthcare practice.

Responses

Congruent with findings related to previous studies exploring medical anatomy students' reports of their own experiences of uncertainty tolerance (Stephens et al., 2021), those found in learners' responses to uncertainty in the broader context of education (Weurlander et al., 2019; Grace et al., 2021) and healthcare literature (Lee et al., 2021; Moffett et al., 2021), this study found academics' perceptions of their learners' emotional responses to uncertain stimuli were predominantly negative. Despite the uncertainty tolerance conceptual model depicting positive emotional responses to uncertainty for healthcare providers (e.g., courage, curiosity, hope), within the learner context there appears to be exclusive reporting of negative responses (Weurlander et al., 2019; Grace et al., 2021; Lee et al., 2021; Moffett et al., 2021). Thus, this overlap between HASS academics perceptions of their non-healthcare students' responses to uncertainty overlaps with those identified in the healthcare student population, further substantiating that identified HASS educators' perceptions of uncertainty tolerance teaching practices may align with the healthcare learning context.

In this study, thematic analysis identified educator perceptions of some positive cognitive and behavioral learner responses, despite educator reports of learners' negative emotional responses. This is consistent with recent data elicited from medical students, wherein students self-reported negative emotional responses to uncertainty, alongside reports of positive behavioral and cognitive responses in the anatomy laboratory (Stephens et al., 2021) as well as medical school more broadly (Nevalainen et al., 2012). This discrepancy between emotional responses as compared to cognitive and behavioral responses may be valuable for anatomy educators to consider when designing uncertainty tolerance inculcated curriculum (e.g., they may not "like" it, but their cognition and behavior suggests improved uncertainty tolerance). This is also an important consideration for universities when they contemplate the timing and approach of student evaluations of teaching, as the strong emotional responses students have to uncertainty tolerance curriculum could affect their rating of teachers and teaching.

State versus trait

This work adds to the mounting evidence that uncertainty tolerance is complex and nuanced, including ongoing discourse about whether uncertainty tolerance is a static personality trait, or a contextually-dependent state. Hillen (2017) suggests that the uncertainty tolerance model can be used to guide research in both (or either) the state or the trait perspective. While at first glance, this seems oxymoronic, this study may help elucidate this apparent anomaly by suggesting that the construct, as a whole, is state-based, and thus contextually dependent, but components may also be trait-based (e.g., objective worldview or humility).

The presence, and apparent impact, of moderators on educators' perceptions of learners' uncertainty tolerance does suggest a largely state-based construct, similar to the limited (but growing) studies within other educational contexts (Han et al., 2015; Strout et al., 2018; Geller et al., 2021; Stephens et al., 2021). However, some of these moderators may, in fact, be traits (or trait-like), such as whether the learner is "humble" or "extrinsically-merit minded" or whether learners' have "subject mastery". Results herein suggest that these "trait"-like moderators, likely do not singularly determine the learners' uncertainty tolerance, but are rather one ingredient in the moderator "soup" impacting learners' uncertainty tolerance. In this way, understanding how, and which, modifiable and unmodifiable moderators impact learner uncertainty tolerance would be an exciting and appropriate next step for anatomical education, and healthcare education more broadly.

Broad practice recommendations

These results contribute new knowledge and suggest practical applications for effectively fostering uncertainty tolerance within healthcare education broadly, and the anatomy education context specifically. Interestingly, many of the teaching practices described by HASS educators provide students the opportunity to safely practice and develop uncertainty tolerance in the classroom through experiential learning prior to entering the healthcare workforce.

Experiential learning's central dogma (Kolb, 1984), relies on transformational learning through varied learner experiences and, when viewing from an 'uncertainty tolerance' lens, is considered along a tri-partite spectrum that includes: (1) "critical incidents" whereby students reflect and link classroom content to real-life experiences (2) "destabilization" that encourages students to act out similar scenarios, and (3) iso-immersion whereby students are embedded in workplaces (placements) (García Ochoa & McDonald, 2019). All study participants described uncertainty tolerance curriculum aligning with one or more of these experiential learning phases. An example is the uncertainty tolerance stimulus of "grey cases", which could represent either as critical incidents (if students are reading about the case) or destabilization (if students are role-playing the case). Moderators could be titrated during each phase (i.e., challenging student assumptions, intellectual candor (Molloy & Bearman, 2019)). Thus, healthcare educators could begin integrating uncertainty pedagogy across a curriculum through purposefully planned experiential learning approaches (e.g., case questions and simulations). This suggestion is further supported by recent findings exploring which types of pre-clinical learning which was perceived as enhancing uncertainty tolerance (Papanagnou et al., 2021). Herein, small group learning and simulations were identified as teaching practices fostering uncertainty tolerance, with simulations reported as helping students to "realize real life is much more fluid and less concrete." Indeed, anatomy educators often engage forms of simulation and cases (experiential learning approaches), through dissection, case studies, and problem-based learning (Torres et al., 2014) both to enhance anatomy learning, and also to illustrate uncertainty intrinsic in the human body. As anatomy education curricular time continues to decrease with a concomitant increase of curricular time devoted to healthcare competency education (Craig et al., 2010; Prober & Khan,

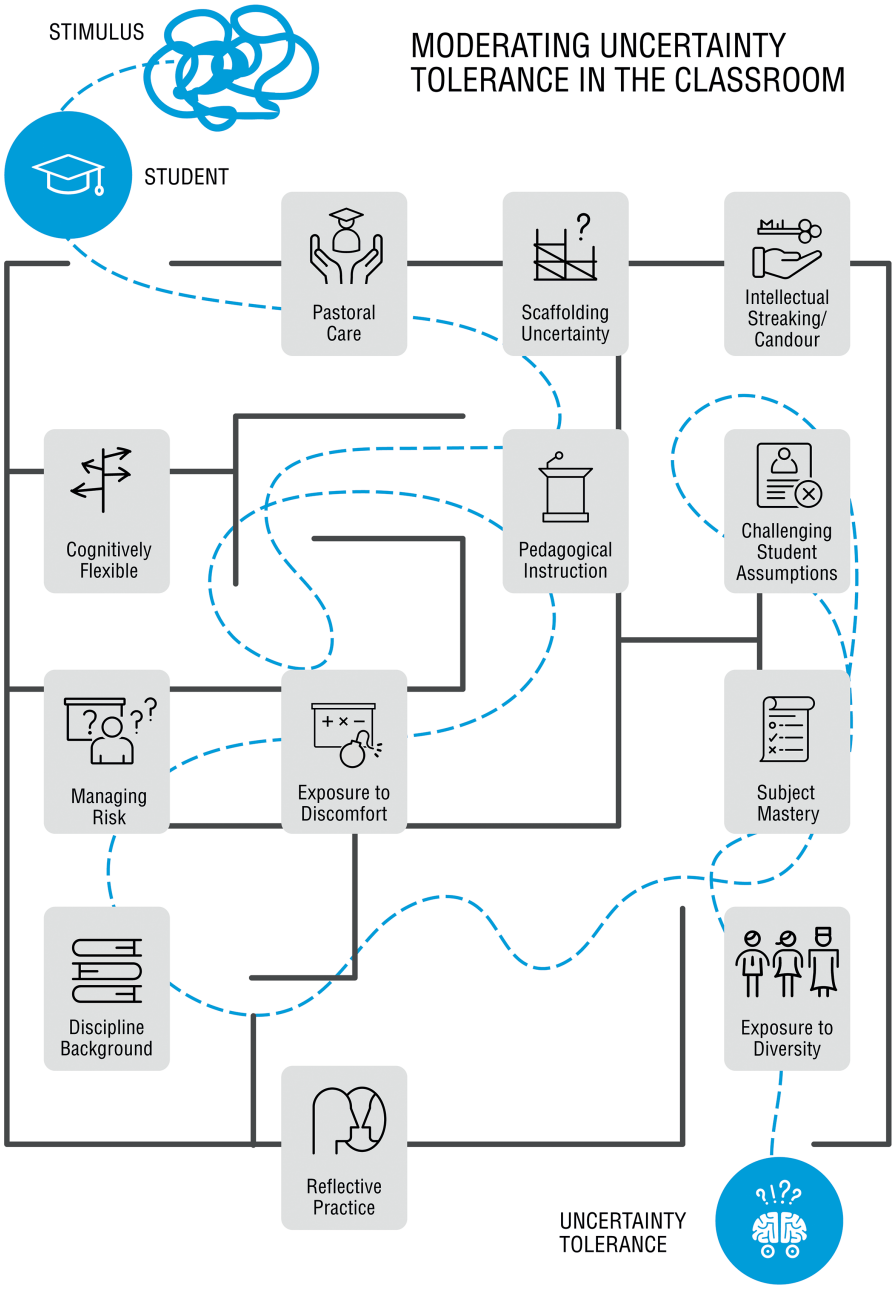

FIGURE 2 Illustration of practical implication of moderator selection in the classroom. Our results, together, suggest that educators have agency to purposefully select moderators, at different timepoints, to foster learners' uncertainty tolerance. Being aware of the context that the educator is teaching within can help them identify which moderator to use when. For example, depending on the selected educational uncertainty stimulus, and knowledge of the learners' personal characteristics, an educator may choose certain moderators (e.g., teaching practices) to help foster uncertainty tolerance in the classroom (represented by the maze)

2013; Trautman, et al., 2019), engaging in teaching practices which foster both anatomy discipline content and uncertainty tolerance healthcare competency becomes both timely and imperative.

Limitations of the study and future work

This qualitative study achieved depth and rigor through purposeful sampling, team-based reflexive coding, and theme development with reference to an existing construct model (Varpio et al., 2017; McGrath et al., 2019; Kiger & Varpio, 2020). This study, however, is not without limitations. Importantly, while educators commented on learners' experiences, learners themselves were not directly studied and conclusions drawn by educators may not accurately reflect the learner's actual experiences. Despite this limitation, study results align with prior work exploring uncertainty tolerance within learners' directly (Moffett et al., 2021; Stephens et al., 2021). In addition, this study did not undertake direct classroom observation, and instead relied on educators' subjective reflections. This may lead to biased recall of experiences and may (in part) be the cause of the high reporting of negative learner responses.

Future work could explore corroboration of educators' stated experiences through direct observational classroom studies and concomitant collection of students' perspectives. This study was completed at a single University in Australia, and thus findings from this study may not be broadly applicable. This limitation is mitigated, in part, by the engagement of an existing model and abductive approach, which enhances the applicability outside the study context (Firestone, 1993). Finally, this study was conducted at a single timepoint, not longitudinally, thus extrapolation regarding the impact of education on learner uncertainty tolerance development over time is not possible. Future research should focus on more deeply exploring moderator interactions and interdependency in the anatomy learning context, as well as investigating the disparate response valences seen across the emotion versus cognitive and behavioral domains across education more broadly.

CONCLUSIONS

The strength of this research lies in the identification of the pivotal, and nuanced, role education can play in fostering learner uncertainty tolerance. Drawing from HASS teaching practices, this exploratory study sheds light on practical and broadly applicable teaching practices for implementation of 'uncertainty pedagogy'. This study also substantiates prior findings in the anatomy learning environment further underscoring that the role that anatomy education, in particular, may be a valuable context for supporting learners' uncertainty tolerance. Importantly, this study suggests that educators' knowledge of the context within which they teach can be harnessed to purposefully foster, rather than hinder, learners' uncertainty tolerance development. This study also illustrates that educators perceive learners' uncertainty tolerance not as pre-determined, but rather as a malleable construct impacted through pedagogical approaches. To quote a participant, uncertainty tolerance should be "… explicitly taught, explicitly modelled, explicitly practiced [sic] …". This transdisciplinary research represents the beginning of a paradigm shift in considering uncertainty tolerance within the higher educational context. The themes identified, including stimulus, moderator and response interactions, is an incremental step forward to inform a larger program of research relating to education (and educators) impact on learner uncertainty tolerance development. Results herein suggest that educators have the power and agency to purposefully integrate uncertainty tolerance teaching practices into their curriculum to better prepare healthcare students for uncertainty inherent in their future healthcare careers.

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