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Research

Engaging science across cultures: building a research community of Buddhist monastics and undergraduate and faculty mentors

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Abstract
Emory University has had a long relationship with His Holiness the Dalai Lama through the Emory-Tibet Science Initiative. Recently the Tenzin Gyatso Science Scholars, who are Tibetan Buddhist monastics that reside and take courses on Emory's campus, were enrolled in a novel science research course designed and taught by undergraduate students at Emory. The goal of this study was to build a research community of Buddhist monastics who worked alongside undergraduate and graduate mentors to complete projects in R1 research laboratories, and the course was designed as preparation for these efforts. The course covered aspects of the scientific method and focused on enhancing engagement and motivation of the Scholars to pursue science research. Knowledge acquisition was assessed through quizzes, affect changes were assessed through focus group interviews, and overall course success was measured through Principal Investigator surveys. Conceptual knowledge and overall average improvement increased significantly week-to-week. Changes in affect for self-efficacy, belonging, knowledge, and future applications/drive trended towards improvement in each respective category. Finally, all seven Monastic Scholars who participated in the research curriculum were enrolled in R1 research experiences after conclusion of the course, and their principal investigators positively evaluated the preparedness and motivation of the monastics. The curriculum detailed here and its implementation facilitated cross-cultural education and successfully transitioned students from the classroom into research laboratories.

Keywords Science education · Cross-cultural education · Buddhism

David Goldberg and George Poppitz have contributed equivalently to the work.

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1 Introduction

In 2008, His Holiness the 14th Dalai Lama, the Library of Tibetan Works and Archives in Dharamsala, India, and Emory University formally launched the Emory-Tibet Science Initiative (ETSI), a unique program aimed at bridging western scientific knowledge and the Tibetan Buddhist monastic tradition [1]. Since then, ETSI has developed and implemented a curriculum designed to teach the thousands of Tibetan Buddhist monks and nuns in exile the fundamentals of biology, physics, and neuroscience. This expansion of the monastic curriculum, the first such significant change in 600 years, reflects the Dalai Lama's continued desire to understand the perspective of, as well as engage in dialogue with, the global scientific community [2].

1.1 Fostering engagement: the Tenzin Gyatso science scholars

Essential to the integration of the two cultures and to building monastic capacity to teach science to their peers are the Tenzin Gyatso Science Scholars, called thus after His Holiness the Dalai Lama's given name, and referred to here as Monastic Scholars. Within Tibetan Buddhism, monastics serve as moral, spiritual, and intellectual scholars, both educating lay people and interrogating the purpose and meaning behind Buddhist texts. This interrogation and critical inquiry encourage an understanding of science, as according to the Tibetan Buddhist tradition, one's worldview is enhanced by understanding others'. The scientific training provided by ETSI therefore gives the monastics a greater understanding of the world and greater capacity to comprehend and educate in Buddhism. Every 2 years since 2011, a cohort of a half-dozen monks and nuns residing within India (having escaped political and religious persecution in Tibet) take undergraduate science courses at Emory with the goal of becoming teachers and translators upon their return to their monasteries in their home countries. These monastics are non-degree, pass-fail students who receive a certificate upon completion of the successful program and have their tuition waived as part of the partnership between Emory University and the Library of Tibetan Works and Archives. Additional travel and lodging funding is provided by the Dalai Lama's office and private donors. Many of them have taken all or part of the 6-year ETSI curriculum in their monasteries and nunneries before coming to the United States. Selection of the Monastic Scholars is a collaboration between ETSI and the monastic institutions. Monastic Scholars are selected based on their scientific and English literacy, as well as their being in an advanced stage within their Buddhist training and monastic careers so that they may possess the skills to be of service such as teaching upon their return. Before leaving India, the scholars are given additional training in English and mathematics to facilitate a smooth transition to undergraduate studies. At Emory, these Monastic Scholars take a variety of science lecture and lab courses alongside other undergraduates. As of 2023, there have been five cohorts of Tenzin Gyatso Science Scholars that have since returned to their monastic communities and become educators and leaders, contributing to the continued spread of scientific knowledge.

The Monastic Scholars benefit from two key programmatic features designed to emphasise and foster their sense of involvement and belonging during their time at Emory. The first element for this is the cohort model, a valuable system for building diverse academic, professional, and social relationships [3]. The second layer is a peer-mentoring program wherein Emory undergraduates and graduate students mentor the Monastic Scholars in courses the Mentors have either previously taken or are currently taking. The peer-mentoring program is built on a conceptual foundation with these overlapping central themes: (1) involvement with learning, (2) academic and social integration, (3) social support, and (4) developmental support [4]. Peers teaching each other and working together may have a larger impact on learning than even classroom instruction itself [5]. Peer mentoring programs assist first-year undergraduate students in developing connections to an institution and feeling a greater sense of belonging [6]; so the philosophy of the ETSI Peer Mentoring Program is to be both an academic and social resource for the Monastic Scholars. There is a positive association between forming social relationships and positive academic outcomes [7]. Furthermore, broad social networks and the ability for students to more easily make connections with others also makes it more likely that they persist in school [8]. When Monastic Scholars arrive on campus they are socially supported and immediately enabled to engage in Emory's academic community.

1.2 Transitioning to research

The greater ETSI project is currently in its fourth stage: the sustainability phase. The central goal of the sustainability phase is to develop a new generation of monastic scientists by integrating scientific research within the Tibetan Buddhist Monastic community. This new phase follows and complements the integration of the ongoing curricular instruction in Tibetan Buddhist monasteries and nunneries [9]. The first three project phases developed a solid foundation of science knowledge within the Tibetan Buddhist community. Currently, science knowledge is required for any monk or nun interested in higher levels of monastic education. In fact, biology, neuroscience, and physics concepts are featured on the Geshe exam, the equivalent to a PhD defence within Tibetan Buddhism. This increasing knowledge of science in the Buddhist monastic community has enabled ETSI to transition from focusing on teaching science fundamentals to developing scientists capable of independent research projects.

With this goal in mind, we developed a curriculum to facilitate the Emory Monastic Scholars in deepening their understanding of the philosophy of science as well as gaining confidence in essential research skills. This was all with the goal of preparing the Monastic Scholars to have authentic research experiences in Emory laboratories. The first key part, teaching the philosophy of science, was accomplished through lectures and discussions on the scientific process and how it provides researchers the tools to ask research questions. By elaborating on the benefits of reproducibility or the essentiality of falsifiable hypotheses, we hoped that Monastic Scholars would be convinced of the utility of personally engaging with research and thus be motivated to learn further. Research skills, from creating hypotheses to using Microsoft Excel, were taught through interactive activities, each designed with a focus on facilitating Monastic Scholars' practice of a specific skill. This project, a 10-week course and accompanying evaluations, received institutional review board (IRB) approval and was implemented in Spring 2022. The IRB determined that although it is human subjects research, it meets the criteria for exemption under 45 CFR 46.104(d)(1). Informed consent was obtained from all individual participants included in the study.

The primary aims of the course were to increase the motivation of Monastic Scholars to engage in the scientific community and to provide them with the capabilities to do so. Motivation and engagement are key components of education, with positive effects on grades, standardised tests, and the ability to better adjust to school [10]. Motivation is a prerequisite and corequisite for learning and is essential for moving students to deeply engage with the type of active learning required in the constructivist models of education we engaged [11]. With the importance of motivation in mind, our curriculum incorporated many motivation-maximising practices [12]. We had clear learning objectives and dedicated the first of the 10 weeks (Table 1) to discussing the purpose and benefits of science so students would understand the motivation for learning the topic. Content and methods were tailored to maximise motivation and focus on activities that empower students. The Monastic Scholars made independent choices, took ownership of experiments, and experienced success through gaining novel information as a result of those experiments. Guided discussion was used to review the previous week's materials, which contributed to creating an environment where both student and teacher input were valued and engaged. As noted by Kaylene C. Williams, motivation must be emphasised in multiple levels of a curriculum [12].

Table 1 Course Outline by Lesson

Lesson	Topic
1	Introduction to the science and the scientific method
2	The scientific method and experimentation
3	Questions and hypotheses
4	Variables and controls: an introduction to experimental design
5	Data analysis part 1
6	Data analysis part 2
7	Reviewing literature
8	Planning and carrying out your experiment: purifying water
9	Planning and carrying out your experiment: purifying water
10	Data presentation

1.3 Cross-cultural science education

One of the foremost challenges facing ETSI is how to teach scientific thought and principles across cultures. The fact that modern science is from a different culture than the students' own was a significant issue faced by educators bringing western curricula to culturally diverse, developing nations such as Afghanistan, Brazil, India, Nigeria, the Philippines, and Papua New Guinea to list only a small portion of participating countries [13]. When students are asked to participate in demonstrations or lectures that directly contradict their own cultural practices, norms, or beliefs this can lead to dissonance and disconnect [14]. Take, for example, describing the value of animal models to a Tibetan Buddhist who holds that all sentient life is equally sacred. A significant gap between the new material and internal values may cause them to not accept the scientific knowledge being taught or to separate it into a different mental category instead of incorporating it into their daily lives. Attempting to force students to assimilate into the culture of western science and forgo their indigenous roots has a negative effect on learning [13], and surface-level rebrands of existing western curricula fail to address the underlying cultural discrepancies [14]. More effective is to have students develop a holistic 'multiple worlds' mindset where the western concepts and their indigenous beliefs comfortably coexist [15].

The Peer Mentors in our project help facilitate a smooth transition as the mentors themselves are from diverse backgrounds and emphasise teaching of multiple perspectives. Rather than attempting to convert the Monastic Scholars to a different perspective, a new perspective is introduced, and the Monastic Scholars are encouraged to debate and discuss it. This leverages the background that the Monastic Scholars have with debate as an active form of thinking and learning [17]; debate is often used in Buddhist monastic education to explore unfamiliar concepts/perspectives [18]. With all this in mind, the hope is that ETSI can provide Monastic Scholars a way to join and enrich the culture of science by participating in actively carrying out science.

The goal of the study presented is threefold: (1) to successfully teach across cultures to help the Tibetan Buddhist monastics successfully create a novel scientific research community; (2) to accomplish this, we created a group of peer mentors who could complement the existing structure of ETSI to help the monastics; and, finally, (3) to develop and implement a scientific curriculum that originated from, and was taught by, these peer mentors. The sum of these effects was the development of a distinctive research community within which the Monastic Scholars independently completed research projects within R1 research laboratories. The preparedness of Monastic Scholars and ability to conduct this research was measured using knowledge scores based on curricula material, affect scores of Monastic Scholars, and feedback from the heads of their research laboratories.

2 Methods

2.1 Curriculum design

There were a total of ten lessons (Table 1) covering steps in the scientific method as part of the research curriculum. This ordering of topics was chosen so that Monastic Scholars would first discuss and investigate the motivation behind research, learn the skills necessary to generate and carry out an experiment, and finally have a chance to employ their new skills in a simple, self-directed research project.

2.2 Affect assessment

Affective changes were explored via a series of pre- and post-focus group interviews over the video conferencing platform Zoom. During the interviews, the Monastic Scholars were asked to report answers using the Likert scale verbally and in writing. To remove social desirability bias [19], all Monastic Scholars were asked to input their answers at an identical time within the Zoom room chat. Two of the Monastic Scholars who answered the question were then asked to explain their reasoning. Volunteers were first asked for comment and after volunteers spoke, the highest and lowest scores were selected and the Monastic Scholars who gave those scores were asked to elaborate on the reasons for their answer. Additionally, if certain Monastic Scholars hadn't voluntarily engaged or given their thoughts in some

Table 2 Code Design (referenced and derived from [20, 21])

Domain	Definition
Self-Efficacy	Participant uses language related to confidence in skills and ability to perform tasks in a scientific research setting
Belonging	Participant shares information related to comfort and feeling at peace in a research setting
Knowledge	Participant mentions their knowledge level on research skills and scientific methodology OR mentioned something they learned from the program
Future Applications/ Drive:	Participant mentions how they want to use what they learned further in their lives OR use terminology related to novel curiosity and exploration

time, they were asked to give their thoughts such that each Monastic Scholar spoke at least three times per session. Questions stemmed from two primary categories: evaluation of a Monastic Scholar's sense of belonging within the scientific community [20] and evaluation of a Monastic Scholar's self-efficacy regarding science [21]. Zoom sessions were recorded for further evaluation and qualitative characterization.

After all of the lessons were complete, the Zoom chat logs were downloaded and the Monastic Scholars' Likert scale scores collected. The Zoom recordings themselves were rewatched and the answers the Monastic Scholars gave to each question were transcribed. Two independent researchers proceeded to code and categorise the Monastic Scholars' statements into four distinct categories: self-efficacy, belonging, knowledge, and future applications/drive (Table 2). After independent coding, the two independent researchers met, examined the entire transcript, discussed discrepancies in coding, and aggregated all coded statements into a single document.

2.3 Knowledge assessment

Conceptual knowledge acquisition was assessed with pre- and post-lesson quizzes corresponding to each lesson, as well as the overall curriculum. These quizzes were comparable to the content and difficulty typically found within an introductory lab course at the undergraduate level. Each pre- and post-lesson quiz consisted of 5 multiple choice questions. Monastic Scholars were given 5 min at the beginning and end of each lesson to complete the quiz. The pre- and post-quizzes consisted of the same questions, but Monastic Scholars were at no point given answers to questions nor feedback on their answers. Each multiple-choice or true–false question corresponded to 1 point so each quiz was scored out of 5 total points. Weekly average improvement was measured by calculating the difference between the average post-quiz and the average pre-quiz scores. Additionally, each individual Monastic Scholar's improvement was assessed by first calculating the difference between each individual post-quiz and pre-quiz, and then averaging these weekly improvements for each Monastic Scholar to assess the per-Monastic Scholar average weekly improvement.

3 Results

3.1 Affect assessment

The differences in average change in Likert scale questions between the pre- and post-test were not significant (paired t-test, $a = 0.05$). Average before and after scores are shown in Table 3. In the final pre- and post-test focus interview groups there was a decrease in the number of self-efficacy and belonging statements from 14 to 11 and 5 to 3 respectively. There was an increase in the number of knowledge statements and future applications/drive from 9 to 20 and 5 to 13 respectively. A sample of these statements are shown in Table 4.

3.2 Knowledge assessment

Weekly quizzes were scored out of a possible five points. The improvement on all weekly quizzes was positive and the average weekly improvement on each quiz was $13.4\% \pm 7.7\%$ (SI Fig. 1) which is significantly greater than 0 ($p < 0.001$, one-tailed t-test, $a = 0.05$). Each Monastic Scholar's individual improvement ranged from 4.4 to 28.8% (SI Fig. 2).

Table 3 Self-reported focus group interview scores

Question	Average pre-score	Average post-score	Average change	P-value
I feel like part of the scientific community	4.1 ± 0.9	3.4 ± 0.8	− 0.71 ± 1.2	0.09
I can use the scientific method to answer questions I have in my life	3.6 ± 0.8	4.1 ± 0.7	0.57 ± 1.1	0.10
I consider myself a scientist	2.7 ± 1	2.9 ± 0.7	0.21 ± 1.2	0.55
How confident are you that you could critique a scientific paper written by another scientist?	1.9 ± 0.9	2.9 ± 1.1	1 ± 1.4	0.02 *
How confident are you that you could provide meaningful feedback on someone else's proposed experiment?	3 ± 0.8	2.9 ± 0.9	− 0.14 ± 1.2	0.79
How confident are you that you could ask meaningful questions that could be answered experimentally?	3 ± 0.8	3.1 ± 0.9	0.14 ± 1.2	0.36
How confident are you that after reading a scientific paper, you could explain its main ideas to another person?	2.9 ± 0.7	3.2 ± 0.7	0.36 ± 1.0	0.25
How confident are you that you could participate in a research lab here at Emory?	4 ± 0.8	4 ± 1.5	0 ± 1.7	1.00

*Indicates statistical significance

Table 4 Selected coded monastic scholar comments

Domain	Pre- count	Pre-curriculum example	Post- count	Post-curriculum example
Self-efficacy	14	'Confidence comes from information and so I feel like I can get more confidence once I have the information but right now I do not' (Monastic Scholar 2) 'I feel like I can get more confidence to understand what I know, but right now I don't have confidence because I have no background in science' (Monastic Scholar 3)	11	'I now feel more confident in investigating not only based on faith but also using the scientific method. So that's why I feel more confident. That's why I am totally confident to participate in a lab' (Monastic Scholar 2)
Belonging	5	'Especially we don't have the opportunity to do research on specific objects and I am excited to be here. I would love to be a scientist but I don't think I am. For me, I never think that I am going to become a scientist because scientists spend their life studying external objects. I would need too high of a level of education or how to use the equipment. I would love to be a scientist but for me, I don't consider myself a scientist. This is my first time to take research sessions so I have no idea what to do and how to do so currently I am not very confident but later maybe' (Monastic Scholar 5)	3	'I am totally aware I am surrounded by the scientific community. I am surrounded by science students and professors learning science so I feel like I am part of the community. Yeah, I am very confident that I'm part of the scientific community…I am confident I am a scientist but can go further' (Monastic Scholar 6)
Knowledge	9	'Actually I have not much knowledge about scientists. After I know more about the body then I can begin to ask more questions' (Monastic Scholar 3) 'However, I currently do not know how the research is done but after a few sessions maybe I would be' (Monastic Scholar 4)	20	'Until participating in Emory, I never learned these subjects. With you guys, I learned a lot of things I never heard about' (Monastic Scholar 2) 'I am more confident because when I was writing the bio notes and looking at websites. Some articles from scientific journals, I could gain main points from what is being said' (Monastic Scholar 4)
Future Applications/ Drive:	5	'I am so curious to learn more about science I don't need to feel embarrassed when we don't know something' (Monastic Scholar 2) 'Especially we don't have the opportunity to do research on specific objects and I am excited to be here' (Monastic Scholar 5)	13	'I love to research because I get new information which is exciting … I am very excited to do research and gained a lot of techniques' (Monastic Scholar 1) 'I love to do investigations using reason and doing deep investigation which is the nature of the scientific method. I am planning to study more on those things in my future time…I think it is also very related to Buddhist philosophy and highly applicable to our life. Your courage while teaching us encouraged me to learn more about labs and other sources. Each and everyone are all excited to learn new things that they have never touched' (Monastic Scholar 2)

Frequencies represent the number of responses that used related themes. (respondent n = 7, utterances coded n = 33 (pre), 47 (post))

Table 5 Principal investigator feedback on monastic laboratory performance

Question	Average score (1–5)	Comments
The Monastic Scholars had an adequate level of general background knowledge before entering my lab (1–5)	3.67	'They had enough background knowledge to be able to get CITI [human subject research] certification and to engage in entering psychosocial data' (PI 1) 'Their background knowledge was sufficient to be able to perform certain tasks in the lab with minimal training. Further, they had sufficient knowledge to ask informed questions about their project. However, their background knowledge was not at a level that would allow them to easily conduct independent research' (PI 2) 'For what we were doing, they did. Having them in the lab is more about them learning about the process of doing science, including experimental design. It was clear they had taken intro bio, because they asked questions about the fungi relative to topics they had learned (i.e., cell division)'(PI 3)
The Monastic Scholars have had enough training in the scientific method or experimental principles (hypotheses, controls, etc.) before arriving in my lab (1–5)	3.33	'They understood enough to engage in research activities; they are strongly interested in learning more and I would like to do a better job of providing a more complete research experience to them' (PI 1) 'The Scholars certainly understand the basis of the scientific method and how to perform work systematically to address a question. But, they are not at the level of being proficient enough to work independently in the lab' (PI 2) 'It wasn't always their first thought to think about why we would need a control, but they did get the reasoning. It's clear they've had less experience doing experiments than the typical Emory undergrad' (PI 3)
The Monastic Scholars have an adequate understanding of the tools employed in research (Excel, mathematics) before arriving in my lab (1–5)	4	'The Scholars had a good understanding of research tools prior to arriving in the lab. Additionally, the Scholars have quickly learned how to use any tools that were novel to them' (PI 2) 'This might be the biggest area they had trouble with. They had trouble with basic computer skills (e.g., download and upload files, use spreadsheets, using scroll bar on side of spreadsheet). For example, after you enter a number, you hit enter. We do this without thinking about it, but they did not know' (PI 3)
How would you rate the Monastic Scholar's curiosity and motivation to learn science? (1–5)	5	'VERY, VERY strong' (PI 1) 'The Scholars are genuinely curious and willing to learn' (PI 2) 'It's always clear they want to do and learn' (PI 3)
Have the Monastic Scholars changed the way science or experiments are viewed within your lab?		'Thus far, they have been helping with data entry' (PI 1) 'It is, perhaps, too early to definitively answer this question. However, I am not aware of major shifts in my lab's thinking or viewpoint' (PI 2) 'It has made [my research assistant] think more about what we are assuming in terms of knowledge we expect people to have. For example, one of the monastics asked about how they could take this back to their monastery, and we take for granted what we have access to. ' (PI 3)
Have the Monastic Scholars changed the way science is performed within your lab or experiments are considered?		'We will be in a better position to engage with them about the big picture soon' (PI 1) 'I don't believe our lab has implemented any specific changes'(PI 2) 'The experiment was started in an undergrad lab class, so it had been designed to be accessible from the start'(PI 3)

3.3 Principal investigator assessment

Finally, all seven Monastic Scholars were matched with research laboratories led by three Principal Investigators (PIs) at Emory University and are currently conducting research projects in areas ranging from fungal parasite interaction to the implementation of a novel curriculum on the effectiveness of reducing burnout in hospital chaplains. We surveyed the PIs for their thoughts on the Monastic Scholars' research, preparation, and contribution to the lab environment. The average Likert-scale scores for those questions are reported below along with a sample of their comments in Table 5.

4 Discussion

4.1 Curriculum creation

In designing a curriculum to help Monastic Scholars transition into university research, cultivating motivation to learn science and desire to engage in research was key. Motivation and active engagement—designing, carrying out, and analysing experiments— play key roles in the instruction of scientific concepts across cultural and educational backgrounds. Motivation is a private process that initiates, directs and sustains goal-directed behaviour [22]. In contrast, engagement is the 'publicly observable behaviour' and is the external involvement with activities [23]. Engagement positively predicts achievement and persistence; it is the 'holy grail' of learning [24]. Previous studies emphasise the importance of student-centred curricula in science education to maintain student motivation to learn [25].

To increase Monastic Scholar engagement, each lesson was built around a central activity. Often taking the form of an experiment, each activity related to that lesson's lecture and was designed so Monastic Scholars could apply the concepts they had just learned with a real example. For instance, after receiving a lecture about the scientific method, Monastic Scholars used each step of the scientific method to investigate how many drops of water fit on a penny. Crucially, the Monastic Scholars were not given a research question; they were given access to many different materials (e.g. different solutions, a mixture of new and old coins, etc.) and each Monastic Scholar generated their own research question.

Using this specific experiment as an example, we observed that Monastic Scholars often generated questions that we had not anticipated when designing lessons. While investigating surface tension on a penny, one Monastic Scholar was interested in exploring whether the penny being on the table or on the floor made a difference in how many drops of water fit on the penny. The Monastic Scholar used each step of the scientific process to answer this question, including designing an appropriate experiment. Thus, we concluded that the lesson succeeded, but nonetheless we were surprised that the Monastic Scholar chose to not use any of the provided experimental conditions and selected conditions that seemed mundane to us. This underscores the importance of student-centred curricula that allowed and encouraged Monastic Scholars to investigate questions that interest them. Anticipating Monastic Scholar interest in a question, like how water purification techniques can be used within monasteries and what water purification techniques are widely used, allowed us to present information relevant to their pursuits and increase motivation.

4.2 Affect assessment—self-efficacy

Qualitative statements reported in the interviews suggest positive improvement in self-efficacy. On matters related to self-efficacy, in SI Table 1, we can see a transformation of the attitude of Monastic Scholar 2, who is initially timid and uncertain of their level of knowledge and how it will translate to being able to effectively perform scientific tasks. After completion of the curriculum, Monastic Scholar 2 suggests that they are comfortable pursuing research both from the perspective of their own faith and from a formal scientific methods perspective. Furthermore, Monastic Scholar 2 suggests that they are comfortable participating in research in a lab environment. This suggests that they have gained the knowledge necessary to comfortably perform research or have gained enough confidence through other forms. Notably, there were some Monastic Scholars who had a marked decrease in scores from before beginning teaching the curriculum compared to after. For example, Monastic Scholar 6 expressed concern for their math abilities, reporting a 1 on the Likert scale and saying 'I don't like math and math doesn't like me. In lab, we need lots of math for the materials. The second thing is that I am not good with memorization' (SI Table 1). During the latter half of the semester, we extensively practised maths and data analytics; so we hypothesise that this Monastic Scholar was previously unaware of the large

amount of maths that they did not know and only after being introduced to new maths topics did they discover their lack of knowledge. This hypothesis is supported by the fact that all Monastic Scholars showed positive weekly improvements on quizzes, each week showed a positive increase in scores, and the average weekly improvement was significantly greater than 0. Taken together, these facts indicate an increase in factual knowledge across all topics. We believe that many decreases in self-efficacy scores after participation in the curriculum can be explained by initial meta-ignorance and then awareness of knowledge gaps similar to Monastic Scholar 6's experience [26].

4.3 Affect assessment—belonging

Before taking part in the course, many of the Monastic Scholars did not see themselves as part of the scientific community. This is exemplified by Monastic Scholar 5's comments expressing a concern with a lack of engagement with scientists, knowledge on how to use equipment, and not having spent years pursuing things they pictured a scientist doing (SI Table 1). This sentiment was very commonly expressed: the idea that they as Buddhist Monastics are doing one thing, and scientists are doing another.

Monastic Scholar 6 had a different take after taking the course. Rather than drawing a divide between professions, they considered themselves as a scientist and expressed a high degree of awareness in how we, as their teachers, and others around them are part of the scientific community. This reveals a strength in the design and implementation of this curriculum. We, teachers of these Monastic Scholars, are also undergraduate students who were peers of the monastics. We attend classes with them and, notably, nearly all of these students are engaged in some form of scientific research. Perhaps since we as their peers and mentors are able to engage successfully in research, they feel they are able to do the same.

4.4 Affect assessment—knowledge

The clearest progression of knowledge statements can be seen in the statements of Monastic Scholar 4. Initially, Monastic Scholar 4 explicitly stated that they did not know how research was performed. During the post-interview, the same Monastic Scholar expressed a significant increase in knowledge and expressed an application of skills learned during the lessons. Specifically, Monastic Scholar 4 expressed an ability to read scientific journal articles and gain information from them (SI Table 1). These skills were taught and assessed during lesson 7 which covered the fundamentals of scientific writing. Furthermore, in order to read journal articles to a satisfactory degree, it suggests that Monastic Scholar 4 was also able to become proficient in nearly all of the topics taught previously on various aspects of scientific methodology.

4.5 Affect assessment—future applications/drive

After taking our class, the Monastic Scholars expressed a strong desire to pursue scientific research experiences. This is unsurprising because the Tenzin Gyatso Science Scholars are selected while in India by their respective monasteries and nunneries for motivation to learn and proficiency in STEM subjects. These comments are therefore consistent with their desire to learn as much as possible throughout their time at Emory University and this desire extended to research as well. Monastic Scholar 2 in particular expressed a high degree of motivation and a lack of concern for making mistakes. Monastic Scholar 2, after curriculum teaching, expressed a desire to pursue science research in the future and continue learning new topics. Moreover, Monastic Scholar 2 also expressed a significant appreciation of the role of science in their life, stating that science research and Buddhist philosophy are deeply related (SI Table 1). This high degree of engagement with the curriculum shows how this Monastic Scholar has thought about how their beliefs are impacted by what they learn as well as demonstrating deeper learning of the lesson materials through cross-cultural integration [16]. These science research lessons appear to have focused some of the Monastic Scholars ideas on how to pursue research and further reinforced any previous interest in science research.

4.6 Knowledge assessment

The increase in knowledge was small but positive each week (SI Fig. 1) and the average improvement on weekly quiz scores was similarly small but statistically significant. Furthermore, each Monastic Scholar had a positive improvement but the improvements were highly variable, ranging from 4% to above 25% (SI Fig. 2). This relatively small and variable improvement makes sense considering that the Monastic Scholars never received feedback on quizzes. It is also worth considering that

most questions required students to apply concepts learned in the lecture. The answers to these applied questions were never given during the lecture which may have contributed to the difficulty and therefore low average scores of the exams. Moreover, these quizzes were given in English, not the Monastic Scholars' first language. A frequent comment would be asking us to help explain questions or translate certain words, however we did not help the Monastic Scholars during quizzes in order to be consistent in terms of results. It is further worth noting the small sample size; measuring increases in knowledge quantitatively would be more meaningful with a larger population.

4.7 Principal investigator assessment and lab placement

To match Monastic Scholars with research laboratories, Monastic Scholars were surveyed on their comfort level performing research with a range of possible model organisms as well as their comfort level with a range of possible actions for each model organism. These options ranged from ethically challenging tasks such as sacrificing insects or mice to more comfortable actions like surveying human respondents. After all seven Monastic Scholars answered the survey, PIs were selected based on their interest and previous experience working with students in cross-cultural contexts. Three PIs were chosen and the seven Monastic Scholars were spread amongst them based on interest.

After the Monastic Scholars actively participated in their respective research labs for a semester, the PIs of the labs were surveyed as well. The PIs answered questions regarding the preparedness and interest of the Monastic Scholars in their respective labs. In aggregate, the PIs reported the Monastic Scholars had the knowledge to begin doing research and understand the process of doing science, although perhaps not yet enough to perform independent research. 'Their background knowledge was sufficient to be able to perform certain tasks in the lab with minimal training. Further, they had sufficient knowledge to ask informed questions about their project. However, their background knowledge was not at a level that would allow them to easily conduct independent research' (Table 5).

In relation to scientific method or experimental principles, a similar consensus emerged: the Monastic Scholars had significant background but 'they are not at the level of being proficient enough to work independently in the lab' (Table 5). In regard to the Monastic Scholars' understanding of research tools, the PIs were more positive, e.g.: 'The Scholars had a good understanding of research tools prior to arriving in the lab. Additionally, the Scholars have quickly learned how to use any tools that were novel to them' (Table 5). The PIs were especially positive about the motivation of the Monastic Scholars. One described their motivation as 'VERY, VERY strong'. Another comment was 'The Scholars are genuinely curious and willing to learn'. Another that 'it's always clear [what] they want to do and learn' (Table 5). These reports from their PIs suggest that the Monastic Scholars were prepared and motivated to actively participate in research when entering their respective laboratories.

4.8 Limitations

One significant limitation of this study is the small sample size. Our sample of seven Monastic Scholars could have skewed findings. This is a significant limitation especially regarding any quantitative metrics such as the Likert-scale scores and the knowledge assessment. Moreover, a larger sample would have been valuable during the pre- and post-interviews as we could have gotten a better sample of statements and understood Monastic Scholar motivation more broadly. Additionally, during the peer-mentored curriculum, Monastic Scholars were also enrolled in Emory's biology majors introductory lab course. This course primarily focuses on laboratory techniques and less on methodology and science philosophy. This course may have influenced Monastic Scholar understanding of scientific methodology or philosophy even though these topics were not the primary focus of the course. Monastic Scholars were also concurrently enrolled in undergraduate science lecture courses including introductory biology and a neuroscience course on sleep during the second of four semesters on Emory University's campus. These additional courses could have contributed to the increase in positive statements qualitatively and the small increase in quantitative measures. The lack of a control group, due to the small population of Monastic Scholars on Emory's campus, makes controlling for variables like concurrent course enrolments impractical for this study.

5 Conclusion

The curriculum detailed here and its implementation, using Peer Mentors to design and teach it, represents a novel attempt at improving cross-cultural education and transitioning Monastic Scholars from the classroom to research experiences. It will be valuable to replicate this effort with a larger set of students. This curriculum was successful at improving

conceptual knowledge and increased affect in self-efficacy, sense of belonging, knowledge and belief in future application/drive. Perhaps most importantly, the course successfully facilitated enrolling all seven Monastic Scholars into professional laboratories and providing them with the tools to have substantive research experiences therein. While the sample size was low, we believe the materials within this paper document a successful pilot study for an attempt at cross-cultural education and should be further explored in subsequent studies to increase the sample size and statistical power. This curriculum and its implementation serves as a model for others with similar goals: successfully disseminating scientific concepts cross-culturally and transitioning students from theoretical understanding in the classroom to authentic research experiences.

Author contributions D. Goldberg, Poppitz, and Sonsurkar took the lead on formulating the project, teaching the course described, collecting and analyzing data, and writing the initial draft of the paper; Manuel, Klaus, and Zhang participated as peer mentors, collected and analyzed data, and contributed to and wrote parts of the manuscript. M. Goldberg and Gray contributed to project design, writing the manuscript, and analyzing data. Eisen, as the director of the program within which the project occurred, provided insight in conceptualization, facilitated writing and shaping of manuscript and provided internal institutional resources for the project. All authors helped write and reviewed all drafts of the manuscript.

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Data availability Any and all original data will be provided upon request to the corresponding author.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate This study (IRB ID: STUDY00003914) successfully met the criteria for exemption under 45 CFR 46.104(d)(1) and was determined to be exempt from further IRB review and approval by the Emory University Institutional Review Board comprising IRB analyst Wayne Patterson, PhD and Senior Consultant HRP Consulting Group on 4/2/2022.

Competing interests None of the authors have any conflicts or competing interests with this project.

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