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Emory-Tibet Science Initiative: Changes in Monastic Science Learning Motivation and Engagement During a Six-Year Curriculum

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Led by His Holiness the Dalai Lama, the initiative taken by the Tibetan Buddhist monastic community to connect with western science and scientists presents a unique opportunity to understand the motivations and engagement behaviors that contribute to monastic science learning. In this study, we draw on quantitative data from two distinct surveys that track motivations and engagement behaviors related to science education among monastic students. The first survey was administered at one monastic university in 2018, and the second follow-up survey was completed by students at two monastic universities in 2019. These surveys assessed the reception of science education related to motivations among monastics and their demonstration of engagement-with-science behaviors. We also tested for variation over time by surveying students in all years of the science curriculum. We identified that monastic students are motivated by their perception that studying science has an overall positive effect and benefits their Buddhist studies, rather than negatively affecting their personal or collective Buddhist goals. In accordance with this finding, monastics behave in ways that encourage fellow scholars to engage with science concepts. Survey responses were disaggregated by years of science study and indicated changes in motivation and engagement during the six-year science curriculum. These insights support the relevance of considering motivation and engagement in a novel educational setting and inform ongoing work to expand the inclusiveness of science education. Our findings provide direction for future avenues of enhancing exchange of knowledge and practice between Buddhism and science.

Keywords: engagement, motivation, emory-tibet science initiative, science education, monasticism

INTRODUCTION AND BACKGROUND

Many theories and conceptual frameworks seek to describe and explain academic motivation and engagement. With the aim of gaining greater clarity in this space, there have been calls for additional co-consideration of motivation and engagement (Murphy and Alexander, 2000; Pintrich, 2003; Martin, 2007, Martin, 2009; Reschly and Christenson, 2012). In the present study we explore motivation and engagement of a unique sample of students: Buddhist monastic university students who participated in a curricular innovation to include science in their monastic education. The educational history of these students includes extensive philosophical training and little to no exposure to western science. We address questions about their motivations and engagement, specifically how these students perceive the value of the science curriculum and the extent to which they participate in activities related to science outside of the classroom. Our goal is to contribute to the ongoing conversation in the motivation and engagement domain through exploration of these concepts in a cross-cultural educational environment.

Motivation and Engagement

Motivation is often viewed as the process that initiates, energizes, directs, and sustains goal-directed activities (Schunk et al., 2012). This motivation process is considered to be a "private, unobservable, psychological, neural, and biological" factor (Reeve, 2012). The positioning of motivation as an internal psychological factor is supported by Ainley (2012) and Martin et al. (2017).

Cleary and Zimmerman (2012) distinguish between motivation and engagement, saying that 'will' reflects motivation and "skill" reflects engagement. This distinction aligns with a cognitive-behavioral conceptualization, with motivation more often seen in cognitive terms and engagement in behavioral terms (Martin et al., 2017).

Engagement positively predicts achievement and persistence and has even been referred to as the "holy grail" of learning (Sinatra et al., 2015). In contrast to motivation, engagement comprises "publicly observable behavior" (Reeve, 2012). Engagement is typically considered to reflect evident and external involvement with activities (Ainley, 2012; Martin et al., 2017).

Suggestions of an underlying connection between motivation and engagement propose that motivation leads to engagement (e.g., Kuhl, 1985; Anderman & Patrick, 2012; Reeve, 2012; Schunk et al., 2012). Longitudinal empirical data tentatively support the idea that motivation provides an impetus for subsequent engagement (Martin et al., 2017). Engagement also explains significant variance in subsequent motivation, ultimately suggesting that motivation and engagement are mutually reinforcing across time and ultimately comprise a cyclical process (Martin, 2012). Reschly and Christenson observe that "motivation is necessary but not sufficient for engagement" (2012).

Motivation and Engagement in Cross-Cultural Education

For the purposes of this study, in accordance with the findings above, motivation is defined as the perceptions of impacts of science learning that influence students' inclination, energy, and drive to continue with the education. Engagement is defined as the behaviors that reflect this inclination, energy, and drive.

Numerous surveys and instruments have been developed for investigation of motivation and engagement including: the Motivation and Engagement Scale (MES) by Martin (2010); the Motivated Strategies for Learning Questionnaire (MSLQ) by Pintrich et al., 1991; the Patterns of Adaptive Learning Survey (PALS) by Midgley et al. (2000); and the Student Engagement Instrument (SEI) by Appleton et al., 2006. These surveys were designed for use with specific age groups of students who are younger than our cohorts who are adult learners. For example, differences in target age are reflected in existing survey items assessing family support of learning. Additionally, items inquired about notes, formal tests, formal grades, which are not as relevant to the science learning experiences of monastics. Finally, existing surveys view future aspirations and goals through the lens of western education, asking questions about the kind of life that is desired as a grown-up (also a question for young students), succeeding later in life, and getting a good job. These are particularly ill-suited questions to ask of students who have dedicated themselves to minimalist Tibetan Buddhist monastic lifestyles.

The Inventory of School Motivation (ISM) by McInerney et al., 2001 has been implemented and assessed in the greatest variety of cultural contexts including with students who identify as Anglo-Australians, Migrant Australians, Aboriginal Australians, Navajo students, and Anglo-Americans (Ali and McInerney, 2005). Additionally, this inventory has been validated in educational settings in Hong Kong and the Philippines (Ganotice et al., 2012; King et al., 2012). The cross-cultural implementation and validation of the ISM supported its potential for use in the context of Tibetan Buddhist monastic science learning; however, similar to the others, this inventory is targeted to students at younger ages (e.g., referencing the role of parents).

Given the limitations of existing instruments in aligning with our study population age and our desire to ask questions specific to the context of students studying science with pursuit of Tibetan Buddhism as the main purpose of their education, we decided to create a novel questionnaire. Motivation and engagement theories have demonstrated validity within science learning experiences in some Western societies, and the relevance of this framework in other cultures remains underexplored. Pajares (2007) specifically called for careful consideration of cultural context in the investigation of academic motivation and consideration of engagement by extension. Here, monastic Tibetan Buddhist scholars reported the impacts of their experiences of science learning motivations and their behaviors that demonstrate engagement with science outside of the classroom.

Introduction of Western Science in Tibetan Monastic Education

The introduction of science in Tibetan monastic education originated from the vision of the Dalai Lama who called for comprehensive science education at Tibetan monastic universities. This call was based on decades of personal experience in dialogue with western scientists from which he concluded that, in many significant respects, Buddhism and western science share common purposes and complementary perspectives (Dalai Lama, 2005).

In 2013, monastic leaders in the Gelug Buddhist tradition decided to implement the science program, ushering in the most substantial curricular innovation in 600 years of monastic education (Gray and Eisen, 2019. The following year, a 6-years science curriculum comprising biology, neuroscience, and physics and supplemented by math and philosophy of science, was introduced in the three largest monastic universities of south India (Gray and Eisen, 2019). This curriculum had been piloted during a 6-years development phase. Introduction in the monasteries was incremental such that the first year of the curriculum was offered in the first year of the initiative, then curricular years one and two were taught the following year, and so forth until all 6 years of the curriculum were implemented. ETSI summer session courses are taught in both English and Tibetan. During class, western science instructors speak a few sentences at a time in English, then an interpreter translates the information into Tibetan. The Tibetan language has roots as a liturgical language for Buddhist teachings, "the language of *dharma*" (Tournadre, 2013). Given these origins, there were few terms for specific scientific phenomena prior to the introduction of science curricula. Through annual translation conferences, over 5,000 scientific terms have been added to the already rich Tibetan language (Gray et al., 2020).

Numerous factors influence the Tibetan Buddhist monastic experience of learning science in this context. Monastic students enrolled in science education are adult learners with a highly developed conceptual framework and are already scholars themselves. These students join the science curriculum after completion of approximately 13–17 years of Buddhist study. Monastic students progressed through each year of the science curriculum in sequence. For example, 5th year participants have been in the science program for 5 years. Examining monastic scholars' motivations and perceptions of this science education experience and related behaviors provides unique and valuable insight on how motivation, engagement and cultural factors can influence science learning.

METHODS

Study Approach

To characterize Buddhist monastics' motivations and engagement related to learning science in the ETSI program, we conducted two studies at two monasteries and time points to yield over 900 monastic survey responses that inform the present report. Specifically, the research questions that these surveys addressed are:

1) How do monastic students self-report their motivations in terms of the impact of science learning on their Buddhist studies?
2) How do monastic students engage in science activities outside of the classroom?
3) Do motivations and engagement related to science learning change during the six-year science curriculum?

Participants, Instruction, and Surveys

During ETSI summer workshops, monastic students attended science class four and a half hours per day, 6 days a week. For each science course (physics, biology, and neuroscience), they received instruction for 7 days, reviewed material on the eighth day, and took a final exam in each topic area at the conclusion on instruction. Each class was led by a teaching team consisting of two visiting faculty, two translators, and a monastic teaching assistant. First- and sixth-year students took an additional class discussing the philosophy of science to bridge their training in philosophy with their science education. Since the workshop was held annually for 6 years, students began science education learning fundamental concepts of each discipline in the first year and pursued topics of increasing complexity through the sixth year. In neuroscience, for example, Year 1 students were taught basic concepts of the neuron, the action potential, and functional neuroanatomy, while Year 6 students grappled with language processing, learning and memory, and consciousness.

A variety of active learning strategies were employed to maintain monastic engagement with science learning, including techniques used by monastics in their own Buddhist study such as debating and the Socratic method of asking and answering questions to engender critical thinking, and traditional western techniques such as hands-on labs, experimentation, and computational learning through interactive videos.

This study aimed to track perceptions and behaviors of Buddhist monastic students as they underwent this novel forum of science education over the six-year curriculum. To this end, two distinct surveys (see **Supplemental Material**) were administered to study how monastics' perceptions and behaviors related to engagement and motivation in science learning and the extent to which studying science affected their Buddhist studies. Further, to investigate how perceptions change over time, and whether they are commonly held across different monastic populations, responses were compared across years of study in the program and at two different monastic universities.

Study 1:

In 2018, monastics from curriculum years 1–5 at Sera Jey Monastic University participated in a survey at the end of the summer session (n = 214). This survey collected self-reported demographic data including level of English proficiency, science education background, and years of participation in the summer science program (**Table 1**). To investigate monastics' perceptions of the role of science in relation to their Buddhist studies, students selected prompts categorized as describing either positive or negative perceptions. Positive perceptions included whether science played a role in shaping, engaging, understanding, or validating Buddhist studies. Negative perceptions included taking away too much time, being a distraction, a contradiction, or not useful for Buddhist studies. To examine specific behaviors resulting from their perceptions and exposure to science, participants rated frequency of hearing, using, and accessing science learning materials outside of class time, as well as their likelihood of encouraging fellow monks to study science on a 5-point Likert scale (1 = none/never, 5 = strongly likely/very often).

TABLE 1 | English language proficiency and science education background among monastic students taking Emory-Tibet Science Initiative (ETSI) science classes in summer 2018 (n = 214).

English language proficiency	Participants (%)
I don't Understand any English	44
When Someone Speaks English, I Understand 50% or more of what is said	51
I am fluent in English	5
Science education background	
I have only studied science in the ETSI Program	46
I have Studied Science in a Secular School	14
I have Studied Science independently	34
I have Studied Science in other Science Programs for monastics, Beyond ETSI	7

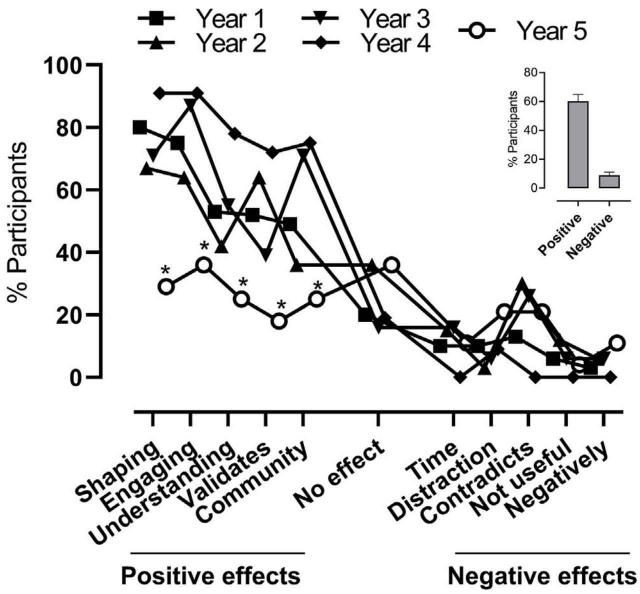

FIGURE 1 | Monastic students' perceptions on effects of learning science at Sera Jey Monastic University (2018 study) In summer 2018, Tibetan Buddhist monastic students reported a robust appreciation for the positive versus the negative effects of learning science on their Buddhist studies; determined by the frequency of survey responses as a percent of participants in each year (n = 214). Each symbol is representative of data from students in different years of the science curriculum. The words chosen as graph labels are underlined in the full prompt (**Supplemental A**, number 7). Overall percent of participants endorsing positive and negative perceptions are quantified in the inset.

Study 2:

To assess the generalizability of initial findings from Study 1, and to probe whether observations at Sera Jey were similar to those at another site where the ETSI program was implemented in a similar fashion, Gaden Monastic University (400 km from Sera Jey), a second survey was administered in 2019 at both Sera Jey (n = 427) and Gaden (n = 296) Monastic Universities to students who participated in years 1–6 of the program. This survey tapped monastic perceptions of gains from participation in the ETSI program at their monastery, including learning science content knowledge, personal gains, and benefits to their Buddhist studies. Participants rated these contributions on a 5-point Likert scale (1 = none/never, 5 = strongly likely/very often).

Translation of surveys used in both Study 1 and Study 2 from English to Tibetan was performed by an experienced monastic translator and then independently verified by a second senior non-monastic translator. Students responded to online surveys given to entire classes in the presence of both the Tibetan-English translator and the western science instructor. All surveys were administered upon completion of the year's ETSI summer program. Survey questions are included as supplemental materials (**Supplemental Material**). Although prompts were communicated to students by English-Tibetan translators, we cannot be sure that definitions, conceptualization, and interpretation of terms were consistent among all survey responders. This is difficult to achieve even when survey items are generated and responded to in the same language and similar cultures (Limeri et al., 2020).

Data Analysis

In the 2018 survey, students were presented with 10 items (five positive and five negative) and asked to choose all items that described their perception of their science learning experiences. The percentages of participants who chose each of the five positive and five negative items were compared across all years of study. A two-way ANOVA examined perceptions (positive, negative) for all years of study (1–6), and their interaction. To assess specific behaviors related to length of exposure to science learning (2018 study) and to investigate the overall associations of science study to science content knowledge, personal gains, and Buddhist studies (2019 study), responses on 5-point Likert scales were averaged, and data are presented as the mean and standard error mean of responses. ANOVAs analyzed behaviors, year of study, and their interaction. For all ANOVAs, Tukey's multiple comparisons post-hoc analyses were conducted to investigate group differences, and effect sizes are reported as R^2. Analyses were conducted in GraphPad Prism version 8.3.0; criterion for significance was $p < 0.05$.

RESULTS

Student Background

To characterize relevant background differences among Tibetan Buddhist monastics in the context of science education, information was collected on English language proficiency and science education history from ETSI students at Sera Jey monastery in summer 2018 (**Table 1**). Responses revealed that 5% of surveyed students were fluent in English (n = 214) and 51% understood at least half of the content communicated through spoken English. Nearly half of the students (46%) were exposed to science education only through the summer intensive ETSI program, 14% of students had studied science in a secular school before joining the monastery, and 34% studied science independently. Anecdotally, students with previous English and/or scientific knowledge often facilitated knowledge exchange in the classroom.

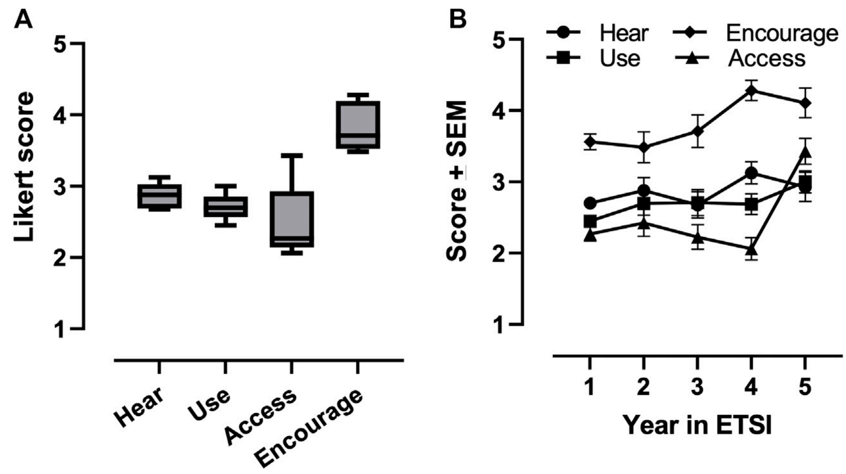

FIGURE 2 | Monastic students' science learning behaviors at Sera Jey Monastic University (2018 study) **(A)** Willingness to encourage fellow monastic students to study science was rated significantly higher on a Likert-type scale of 1-5 than practical behaviors of hearing science words, using science terms, and accessing science content outside of ETSI ($n = 214$). **(B)** Disaggregated by year of study in ETSI, monastic student levels of engagement increased as a function of years in the program. In particular, accessing science materials significantly increased with Year 5 students compared to all other years; $p < 0.0001$; Tukey's test. Each symbol is representative of a different science learning behavior.

Monastic student perceptions and behaviors related with ETSI science education at Sera Jey Monastery (Study 1, 2018)

A high percentage of monastic students endorsed positive effects of studying science on their Buddhist philosophical and religious studies (**Figure 1**, inset). Across all years of participation in the science curriculum, 57 - 71% of monastics identified some positive effects, while only 4 - 30% of monastics selected negative effects. The number of reported positive and negative perceptions differed significantly, F (1, 4) = 19.88, $p < 0.05$, $R^2 = 0.74$.

Among positive statements, those most frequently selected across all years of science study were that science learning helps in: 1) engaging other philosophies in understanding Buddhism (70.6%) and 2) shaping what it means to be a monastic in the 21st century (67.6%). Further analysis detected a significant and robust effect of years in the program on positive perceptions of studying science, F (4, 16) = 23.85, $p < 0.0001$, $R^2 = 0.70$. Notably, year 5 responses were significantly lower for all positive effects compared to those of students in early years, $p < 0.0001$. Among the negative statements, the most frequently selected across all years of science study were that learning science: 1) contradicts Buddha's teachings with respect to origins of life and the universe (18%) and 2) harms my Buddhist studies because it requires too much time. (10.4%). We observed a significant effect of years of study (F (4, 16) = 3.35, $p < 0.05$), but with a small effect size, $R^2 = 0.30$, in which Year 4 students less frequently endorsed four of the five negative effects compared to students in all other years.

With respect to science learning behaviors, monastic students in all years of study strongly endorsed the likelihood of encouraging fellow monastics to study science, with the highest mean Likert scores (3.8 ± 0.1), and with lower scores on hearing (2.8 ± 0.1), using (2.6 ± 0.1), and accessing (2.4 ± 0.1) science concepts outside the classroom. (**Figure 2A**). To further investigate trends in engagement with science material outside of class, a two-way ANOVA revealed a significant effect of year of study on reported behaviors F (4, 1,040) = 13.77, $p < 0.0001$, $R^2 = 0.04$ and a significant interaction between year of study and behavior, F (16, 1,040) = 2.49, $p = 0.001$, $R^2 = 0.03$. (**Figure 2B**). In particular, Tukey's post-hoc tests comparing all possible combinations revealed that Year 5 students more frequently reported accessing science information in the Tibetan language than did students ($p < 0.0001$, comparing Year 5 to all other years). Furthermore, scores on the relevance of science in Buddhist studies and on encouraging fellow monastics to study science significantly increased over time, based on comparison of Year 1 to Year 4 responses ($p < 0.01$, comparing Year 1 to Year 4 responses).

Monastic student perceptions regarding benefits of science learning at Sera Jey and Gaden Monastic Universities (Study 2, 2019)

The second study aimed to elicit additional perspectives on the benefits of science education. At both monasteries, monastics reported significantly lower mean scores on actually learning science as a benefit of participation in the science curriculum, compared to personal gain or benefits to Buddhist studies, $p < 0.0001$ and $p = 0.0003$ for Sera Jey and Gaden, respectively (**Figure 3A**). Further comparison by two-way ANOVA (monastery x benefit) revealed no significant interaction or difference between the two monasteries for each perceived benefit F (2, 2,169) = 0.26, $p = 0.61$.

Analysis of responses by year of study in ETSI revealed that for both monasteries, all perceived benefits increased among students from Years 1 through 4, yet mean Likert scores were lower among Year 5 and 6 students (**Figure 3B**). Two-way ANOVAs identified

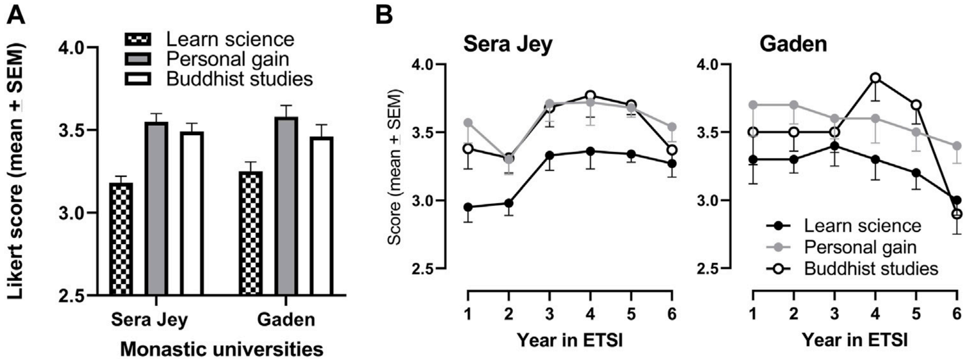

FIGURE 3 | Monastic students' perceptions on benefits of learning science at Sera Jey and Gaden Monastic Universities (2019 study) **(A)** At Sera Jey and Gaden monasteries, monastic students rated learning science content as a benefit of participation significantly lower on a Likert-type scale of 1-5 compared with personal monastic gain or benefits to their Buddhist studies, $p < 0.0001$ and $p = 0.0003$ for Sera Jey and Gaden, respectively. **(B)** At Sera Jey and Gaden monasteries, all perceived benefits increased as students responded from Year 1 to Year 4, and Likert scores began to decline for the Year 5 and 6 students. Each different circle style is representative of different perceived benefits of learning science.

a significant effect of participating year in science curriculum on reported benefits gained by science education, F (5, 1,260) = 6.5, $p < 0.0001$, $R^2 = 0.02$ and F (5, 999) = 3.7, $p < 0.01$, $R^2 = 0.02$, for Sera Jey and Gaden, respectively.

DISCUSSION

Monastic students report a robust appreciation for the positive effects and benefits of studying science on their Buddhist studies

The robustly positive effects we observed likely are linked primarily to the perceived connections between science learning and enhancing Buddhist studies. For example, the most frequently selected positive effects of studying science were that 1) it contributes to shaping what it means to be a monastic in the 21st century and 2) it is a means of engaging other philosophies to help the development of Buddhist philosophy (**Figure 1**). Students also affirmed that science learning benefits their Buddhist studies and produces personal gain to a significantly greater degree than the inherent learning of science (**Figure 3A**). These findings detail specific positive perceptions that monastics endorse about their science learning experience. Notably, these findings are found in the Year 1 through Year 4 students, whereas Year 5 monastics' positive perceptions declined significantly. This difference could be attributed to two opposing forces. Year 5 and 6 students begin preparing for the rigorous Gelug exams, while Years 1 through 4 are enthusiastic for the summer enrichment that ETSI brings, temporarily changing the demanding year-round schedule of the monasteries.

Monastic students enthusiastically encourage fellow monks to engage in and study science

As shown in **Figure 2**, students reported on average that they "sometimes" 1) hear science terms being used by Tibetan monastics (e.g., in conversations, debates, teachings), 2) use science terms outside of the summer program, and 3) access science content in the Tibetan language on the internet, social media, news, or radio. In contrast, the likelihood of their encouragement of fellow monastics to study science was significantly higher.

Despite the strength of personal beliefs that science learning can positively influence their Buddhist training, the significantly lower scores on hearing, using, and accessing science compared to building a community of science-learning monastics, suggest that the practical utility and frequent exposure to science concepts may be limited. Such a finding indicates that conceptual buy-in is farther along than the more pragmatic coordination aspects that are needed to more effectively promote science learning behaviors outside of the ETSI classroom.

Personal and behavioral factors related to learning science change with science exposure across the six-year science curriculum

A notable finding of this study is the change in perceptions and behaviors related to science learning as a function of year in the ETSI program. As monastics participate in consecutive ETSI summer programs from years 1 through 4, they increasingly report positive effects of the experience (**Figures 1**, **3B**), are more likely to refer to science concepts outside of the classroom setting, and increasingly encourage fellow monastics to pursue science education (**Figure 2B**). However, monastic students' perceptions on the benefits of science education significantly decrease in Years 5 and 6 (**Figures 1**, **3B**, respectively). We suggest that these changes are attributable to the competing demands of participation in the ETSI summer program against increasing pressure to study for the Gelug Buddhist exams taken by many Year 5 and Year 6 students. As monastics reach advanced stages of their Buddhist studies, they become eligible to start taking the Gelug exams for the highest academic Geshe degree. Monastic students in Years 5 and 6 expressed concern that participation in science studies eroded time for adequate preparation for those all-important exams. For example, it was reported by monastic science directors that scholars enrolled in these years sought exemption from labs (Sera Jey) or from the science classes entirely (Gaden). By contrast, monks in the early years of ETSI may be more likely to participate in science activities throughout the year, in addition to the ETSI summer program.

Consistent differences in monastic students' perceptions of the benefits of learning science in the earlier versus later years of science exposure are maintained across two monasteries, as well as in Study 1 (2018) and Study 2 (2019) (**Figures 1**, **3**). The pressure of limited time to study while attending science classes appears to be a barrier to sustainability of positive science learning perceptions. Nevertheless, the inclusion of formal science knowledge assessment on the Gelug Buddhist exams appears to stimulate students accessing science education materials (**Figure 2B**), consistent with the need to study and prepare for the science sections of the exams.

Incorporating more frequent, habitual exchange of information *via* routinization of science classes throughout the entire year (not only summer) may enhance the currently modest access to science reported by students in Years 1–4. Implementation of such a year-round class schedule is underway. Encouraging incremental, time-distributed and structured use of science learning materials outside of class in Years 1–4 may buffer disaffection from science studies among Year 5-6 students (**Figures 2**, **3**, and 4) by better preparing them for science questions in their Gelug exams, and reducing the scramble to access science materials in years 5 and 6 (**Figure 3B**), thereby lowering conflict with urgent demands for Buddhist studies.

Implications and Broader Impacts on Science Education

Motivation

Here we have considered motivation and engagement of monastic students in science. Our findings frame the driving force behind monastic scholars' motivation for learning science in terms of their personal grounding in and dedication to the study of Buddhism. The quantitative data presented here show that acquiring science content was the least frequently endorsed benefit of the ETSI experience, compared to personal gain as a monastic, or advancing their Buddhist studies. Qualitative analysis of monastics' interview statements in a separate parallel study, also found that students consistently drew associations between Buddhist training and their appreciation of science education (Worthman et al., *this issue*). The overarching interest in ETSI science education opportunities appears to arise from monastics' perception that science may offer fresh knowledge and insight (Worthman et al., *this issue*), which aligns well with values and practices in the Tibetan Buddhist monastic culture oriented to knowledge attainment and understanding.

Our results underscore the necessity of student-centered curriculum and instruction across cultures and scientific backgrounds in order to maintain student motivation to learn (Stebleton et al., 2012). Non-STEM students taking science courses to fulfill college General Education requirements are similar to our monastic science students in that future aspirations are not necessarily centered on science. Monastics' biology questions related primarily to personal interests and experiences. For example, they are intrigued by the sensory system which renders us sentient beings; the abstract nature of the mind versus physical brain; and the physiological underpinnings of meditation. Pursuit of this type of knowledge maintained their motivation to learn. This is consistent with the suggestion that exploring connections between science course materials and the strengths, values, and aspirations of our learners enriches and promotes discussion of science through a multi-disciplinary lens (Stebleton et al., 2012). Future studies that formally investigate first-order factors that comprise motivation, a higher order factor, will complement the findings of this current study. Such first order factors include: self-efficacy, valuing, and mastery orientation (Martin et al., 2017). In particular, documenting changes in these constructs over time will provide valuable insight into the unfolding effects as monastic science education progresses.

Engagement

In addition to assessing motivation, engagement was considered in terms of behavioral factors to determine the actualization of perceptions of motivation. Survey responses in the present study and interview responses in Worthman et al. (*this issue*), indicate that monastic students value science education for advancing their pursuit of enlightenment and are motivated to learn. The extent to which this motivation translates into active engagement with science-seeking behaviors outside of class changes throughout the course of a student's science learning. The hypothesized primary cause of these changes is increased time demand for Buddhist studies as students progress through this parallel coursework. Advanced monastic Gelug exams take place in the 5th or 6th year of the science curriculum. To investigate the long-term effects of science learning, further studies that examine behaviors of monastics who have completed the 6th and final year of the ETSI program are warranted.

We propose that inclusion of more science topics and more opportunities throughout the year to explore science in this traditional monastic setting, and use of monastic learning styles such as debate can facilitate increased engagement and a more complete integration of science education into the monastic curriculum (Tillemans, 1989). Additional investigation of first-order factors that are components of engagement, including planned behavior and monitoring, task management, and persistence (Martin et al., 2017), will expand the foundation provided by this current study. In particular, exploring the development of these constructs over time in parallel with first-order factors of motivation (self-efficacy, valuing, and mastery orientation) will enrich the knowledge of co-consideration of these concepts.

Motivation and Engagement for Program Sustainability

Students' motivation and engagement related to learning play a significant role in retention and enrollment (Seymour and Hewitt, 1997; Gasiewski et al., 2012). It is therefore important to consider our findings in relation to ensuring the longevity of the partnership between science education and Buddhist monastics. Gathering information about the current state of monastic scholars' motivation and engagement with science education is key to the sustainability of this endeavor.

Our study reports on a novel setting for engendering student motivation and engagement in science learning. Moreover, our findings provide evidence that implementation of a science education summer program for a culturally diverse and non-STEM student body can be successful if implemented over several consecutive years. Because of the highly preserved traditions of the Tibetan Buddhist monastery culture, we make the assumption that the language proficiency and science background of the monastic students collected at Sera Jey are likely to be very similar to those of the students at Gaden monastery. Nevertheless, regardless of the possibility of differences in these specific demographics, our findings support marked similarities across the two institutions for the outcomes measured.

We observed changes in motivation and engagement over the course of the six-year curriculum. We predict that changes will continue as these students move on to the next stages of their training. Additionally, we may expect changes in the motivations and engagement of new, incoming students as they join the science curriculum at different stages of its institutional maturity.

Now that all 6 years of the science curriculum have been fully implemented, focus has turned to building science pedagogy skills among monastics and lay Tibetan scientists who henceforth will conduct the science program. In partnership, the monastic universities and western universities are currently undergoing a shift of primary science teaching responsibilities from visiting science professors from abroad to science classes taught by Tibetan Buddhist monastic instructors and lay Tibetan instructors in the community.

Success during this stage is key both to the sustainability of the program and evolution of the curriculum within the Tibetan Buddhist monastic teaching and learning context. Drawing on knowledge of student motivations and engagement will fully realize the enormous potential of students as co-creators of content and teaching approaches.

An encouraging practice to emerge from this partnership is the increasing collaboration and engagement between monastics and Western scientists on original scientific research resulting in publication of books and articles, including Buddhism-informed science education and neuroscience research investigating brain activity during monastic debate (Lakshmi, 2017; Eisen and Kunchok, 2018; van Vugt et al., 2018). Public health projects related to diabetes, depression, and water quality have also been initiated in the monastic communities.

Monastic science education will build on this momentum to increasingly incorporate monastic students as co-creators of science content through explicit discussion between science and Buddhist concepts and utilizing monastic-specific teaching approaches, e.g., debate between a challenger and a defender (Tillemans, 1989; Osborne, 2010; Simmons and Prunuske, 2015). Western Biology educators realize the enormous learning potential of students as co-creators of content and teaching approaches such as active peer-mentoring in supplemental instruction (Achat-Mendes et al., 2020), and in this second phase, the train-the-trainer model will employ monastic students as co-creators of science curriculum.

Notably, the intentions of monastic education differ markedly from traditional western education. Specifically, in Tibetan Buddhist monastic education, studies are undertaken with the lifetime aim to transform the mind toward attaining enlightenment, a process that generally takes many lifetimes. This presents a very different worldview and context to learning motivations as compared with those common in western education. Academic studies are often undertaken in western society with the goals of proving oneself, gaining status, accreditation and earning a high wage in a career.

Future studies untangling the myriad of possible effects these long-term goals may have on more immediate science learning perceptions will provide valuable insights. For example, a longitudinal study could be conducted by selecting students in their first year of science study and observing changes in learning motivations and engagement with science over time. Future studies may continue to consider motivation and engagement in order to gain additional insights into the cross-cultural applicability of this approach. Findings related to this student population provide unique insights relevant to understanding the breadth of motivations that students bring to the classroom and the diversity of means of engagement.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Emory University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. The Institutional Review Board of Emory University approved the procedures for this study (IRB00073805). Given the de-identified and archival nature of the data, an informed consent process was not required.

AUTHOR CONTRIBUTIONS

All authors listed have made substantial direct and intellectual contributions to the work, and approved it for publication. Specifically: Study concept and design: all authors. Data collection: CA-M and CW. Data analysis: CA-M, KG, and AK. Writing: KG and C-AM with feedback from all authors.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2021.724121/full#supplementary-material

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