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Boundary Crossing by a Community of Practice: Tibetan Buddhist Monasteries Engage Science Education

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As a globalized world struggles with division and disinformation, engaging across difference has emerged as a major challenge to communication and collaborative action needed to address growing global challenges. As such, the initiative by Tibetan Buddhist leaders to incorporate western science in curricula for monastic education may serve as an important case study that illuminates the conditions and processes at work in genuine cultural outreach and exchange. That project, spearheaded in the Emory-Tibet Science Initiative (ETSI), involves reaching out across two quite different communities of practice, Tibetan Buddhism and science, and the willingness and ability of individuals to cross the boundaries between them. In the study reported here, we apply existing understandings of communities of practice and of learning mechanisms that mediate boundary crossing to probe for presence of conditions and processes that promote effective outreach among Tibetan Buddhist monastic students. We deploy analysis of qualitative survey, interview, and self-report data from monastic students shortly after ETSI began (2009) and after science education had been rolled out in the monasteries (2019) to, first, identify initial cultural conditions related to outreach and engagement with science, and, second, probe for post-rollout presence of boundary crossing learning mechanisms among monastic students which facilitate communication from one community of practice to another. We found a range of robust initial cultural conditions (e.g., perceived overlap in subjects and methods of inquiry), along with strong presence of mechanisms that facilitate boundary crossing (e.g., reflection, transformation) and operate through time. We observed cascading effects of these conditions and mechanisms on student engagement with science. Furthermore, interactions of these conditions and mechanisms allow monastic students to engage with science on their own Buddhist terms and to regard learning science as potentially beneficial rather than threatening to their personal or collective Buddhist goals.

Keywords: monasticism, cultural outreach, boundary crossing mechanisms, Emory-Tibet Science Initiative, science education, learning mechanisms, community of practice

INTRODUCTION

In January 2008, the Dalai Lama formally announced the launch of an initiative in monastic science education to an audience of over 30,000 monastic and lay attendees during a major teaching at Drepung Loseling monastery in India. The leading figure in Tibetan Buddhism within and outside Tibet, His Holiness articulated the rationale for this bold undertaking and placed the authority of his imprimatur on it. The announcement of the Emory-Tibet Science Initiative (ETSI) had been prefigured by decades of his own dialogues with western scientists, speeches to the monastic community about the value of engaging with western science, and various small-scale programs to teach science to monastics (Dalai Lama, 2004). The new initiative aimed to bring western science education into the mainstream of monastic curriculum itself. [Note: Here we abbreviate western science as "science" while recognizing the wealth of science systems across cultures (Janes, 1999; Zidny et al., 2021)].

Such a commitment to outreach by an ancient, prominent, and culturally and socially complex tradition such as Tibetan Buddhism to another powerful, similarly complex and established yet quite different tradition such as science rarely occurs and, sceptics might think, may put the host tradition at risk for irrevocable change. Existing research on communities of practice such as Tibetan Buddhism or science has identified conditions that drive their development and welfare (Wenger et al., 2002), while a related literature has identified mechanisms that mediate successful boundary crossing between communities of practice (Akkerman and Bakker, 2011). In this report, we begin by reviewing literatures on communities of practice and boundary crossing, the history of ETSI, and precedents for cultural outreach in Tibetan history, followed by rationale for the focus on monastic students in the present study. Then, we deploy analysis of qualitative survey, interview, and self-report data from monastic students to identify initial cultural conditions for outreach and engagement with science, and probe for presence of boundary crossing mechanisms that facilitate communication and exchange from one community of practice to another. Note that this study is partnered with a related quantitative study also included in this special issue.

In a globalized world that struggles with division and disinformation, engaging across difference has emerged as a major challenge to collaborative action needed to address growing global challenges. As such, the Tibetan Buddhist monastic establishment's project to engage with science may serve as a valuable case study that illuminates conditions and processes at work in genuine cultural outreach and exchange.

Boundary Crossing and Communities of Practice

Defining characteristics of communities of practice are that its members identify with a common purpose, interact constructively and often, and cultivate shared cumulative learning to pursue their common goals (Lave and Wenger, 1991; Wenger, 1998). By these criteria, the monastic communities in Tibetan Buddhism and in western scientific communities each represent recognizable albeit diverse communities of practice formed by distinctive purposes, interactions, and epistemologies that characterize members' identities, attitudes, behavior, and to a large degree, worldview (Hacking, 1983; Lopez, 2008).

Successful encounters between communities of practice involve boundary crossing, where the boundaries are not merely physical but also epistemological, behavioral, affective, and sociostructural (Shore, 1996). This is especially true where the community of practice is large, established, and essentially constitutes a culture or subculture. Social sciences investigation of boundaries and boundary crossing has intensified in response to escalating forces of globalization and social change alongside urgent needs for diversity and inclusion (Engeström et al., 1995; Lamont and Molnár, 2002; Akkerman and Bakker, 2011). A growing body of theory and evidence engages both ecology and processes of boundary crossing. Social ecology drives impetus and informs outcomes of boundary crossing that arise from contextual push/pull factors such as social structure (Friedman and Podolny, 1992; Soundararajan et al., 2018), resource demand and allocation (Hawkins et al., 2016; Risien and Goldstein, 2021), cultural forces (Denner et al., 2019), and power dynamics (Goldstein et al., 2017; Collien, 2021). History, too, plays a largely overlooked role (Ravishankar et al., 2013).

Boundary crossing processes themselves have been investigated as sites for learning (Walker and Creanor, 2005; Caruana and Montgomery, 2015; Boulton, 2019), collaboration and innovation (Carlile, 2004; Penuel et al., 2015), and organizational change and navigation (Walker and Creanor, 2005; Yagi and Kleinberg, 2011; Hawkins et al., 2016; Risien, 2019). Such processes appear central to education, particularly STEM education, where students and teachers need to develop skills to engage in scientific discourse within diverse communities, as well as the ability to leverage strengths of collaborators' multiple perspectives (Austin, 2018). Integrating multiple worldviews in the learning environment has been associated with increased number and diversity of STEM graduates, better learning in the classroom, science experimentation, discovery, and knowledge, and ultimately more creative and skilled scientists (Hartfield-Méndez, 2013; Bouncken et al., 2016; Jackson et al., 2016). Facilitating boundary crossing also has proven useful for establishing continuity between the teaching community of practice and education researchers (Bakx et al., 2016).

This expanding body of work suggests that boundaries are inherent features of human social life that can serve as learning resources, rather than as barriers to productive engagement (Collien, 2021; Leach, 2001; Risien and Goldstein, 2021). Findings highlight boundary crossing as essential to learning (Akkerman and Bakker, 2011; Wenger-Trayner and Wenger-Trayner, 2015), and distinguish key elements of boundary crossing processes, namely agents, objects, and mechanisms. Agents, or boundary spanners, come in many guises, including as internal actors negotiating exchange (Thomas, 1994; Sturdy and Wright, 2011), or mediators of task orientation or socioemotional connection (Friedman and Podolny, 1992; Weerts and Sandmann, 2010), or power brokers who leverage conditions for engagement and innovation (Ryan and O'Malley, 2016; Collien, 2021; Wegemer and Renick, 2021). Boundary objects have been recognized to play crucial roles as mediating entities that bridge communities of practice by being legible for all participating communities while also sufficiently multivalent to represent internal value for each (Star and Griesemer, 1989). As co-constructed community-bridging artefacts, boundary objects can be material (documents, physical spaces), abstract (ideas, neologisms, norms), behavioral (rituals, practices) or animate (transdisciplinary student). Hence, "creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds" [(Leung, 2020), *p*. 3]. As such, boundary objects have been closely studied as powerful agents in knowledge-sharing and collaboration (Carlile, 2004).

Learning may involve boundaries, but how is their learning potential realized? A review of learning-focused studies that examined boundary crossing has identified four mechanisms of learning that underlie boundary exchange—identification, coordination, reflection, and transformation (Akkerman and Bakker, 2011, see also **Table 2**). Each class of learning mechanisms comprises distinct processes. In the first, identification, boundaries between practices become uncertain or destabilized through two processes, othering (sharpening contrasts) and legitimating coexistence (identity redefinition, boundary reconstruction). The second, coordination, allows diverse practices to cooperate efficiently in distributed work through three processes: communicative connection (exchange, translation), increased boundary permeability (smoother interactions), and routinization (automatization, normalization). The third, reflection, involves realizing and explicating differences between practices in order to learn about one's own and others' practices via two processes, perspective making (delineating one's perspective) and perspective taking (seeing the other's point of view). The fourth, transformation, entails collaboration and development of new practices, effecting social change that involves six processes–confrontation (recognizing a conceptual or pragmatic gap that requires both parties to re-evaluate existing practices), recognition of shared problem space (shared concerns), hybridization (create new cultural forms), crystallization (reification, institutionalization in new practices), integrity maintenance (sustain uniqueness of the intersecting practices and thus, boundary crossing), and continuous joint work at the boundary (required to maintain productivity of boundary crossing).

Subsequent research has applied the Akkerman and Bakker schema for mechanisms of boundary crossing for many purposes, including production and evaluation of educational programs (Leung, 2020), math teacher training designing research-practice partnerships (Fjørtoft and Sandvik, 2021), and serious game design (Delima et al., 2021). Here, we apply it to analysis of monastic students' reports about engaging with science.

The Emory-Tibet Science Initiative

In 2006, the Dalai Lama and Emory University forged a partnership to establish western science education in Tibetan Buddhist monastic universities. During the 2008–2013 development phase, teams of western scientists iteratively prepared and tailored a multi-year program with curricula in areas monastic leaders considered most relevant for Tibetan monastics. In 2013, leaders in the dominant school of Tibetan Buddhism, the Gelugpa, decided to implement the resultant science program, ushering in the most substantial curricular innovation in 600 years of monastic education. Consequently, the 6-years science curriculum comprising biology, neuroscience, and physics and supplemented by math and philosophy of science, was introduced that year in intensive summer programs at the three largest monastic universities of south India (Gray and Eisen, 2019). Implementation of the roll-out was completed in Summer, 2019, by which time science education was institutionalized in participating universities, the monasteries took over science education, and ETSI transitioned to a sustainability phase focused on building in-house capacity for science pedagogy and research (Worthman et al., in press).

The science initiative constitutes cultural outreach, wherein the monastic community invited the western scientific community to share concepts, methods, and knowledge without expectation that, reciprocally, the scientific community must engage seriously with Buddhism. Western scientists were requested to represent the scientific fields on their own terms, rather than try to adapt scientific disciplines for exchange with Buddhism *per se*. Monastics aimed to learn core logics, practices, key concepts and insights of the focal fields–physics/cosmology, biology and neuroscience–while the science educators sought to present them as clearly and accessibly as possible (Worthman et al., in press). Yet more was expected than lectures, lab exercises, and vocabularies. Tibetan Buddhism is a text-based tradition, from the recorded collection of the Buddha's teachings through centuries of written commentaries and revealed teachings (*terma*). As such, ETSI was asked to produce texts that provide a basis for teaching and study. Hence, ETSI faculty wrote a series of 16 condensed texts, or primers, one for each of the 5 years of the curriculum in each of the three disciplines, plus one for philosophy of science. Throughout, translators played key roles, working with ETSI faculty to produce a science lexicon in Tibetan and mediating communication in classroom and texts. All texts comprise facing pages of corresponding Tibetan and English content. These materials, together with rapid turnover of science education to the monastic universities, served as important boundary objects and created a basis for the monastic community to learn, critically engage with, and intellectually process science on their own terms. The goal was not necessarily to produce monastic scientists, but science literate monastics who could engage with science on an equal intellectual footing.

In sum, the ETSI spearheads a Buddhist-initiated collaborative project with western science for knowledge transfer toward sustainable science literacy in the monastic community that will provide grist for thought and analysis, and charge examination of modes of inquiry and knowledge production with an aim both to advance development of

Buddhism and to enhance its value for all sentient beings. His Holiness the Dalai Lama jokingly has remarked that the project would proceed quickly and take merely a hundred years or so.

Cultural Outreach and Innovation in Tibetan History

Engagement by Tibetan Buddhism with western science has firm historical precedents. Tibetan history is distinguished by signal moments of cultural outreach that have had defining impact on the course of Tibetan society (McKay, 2003). Such turning points go back to the 7th Century with first formation of an expansive centralized state under the Tibetan King Songtsen Gampo, who introduced Buddhism to Tibet and sent a minister, Thonmi Sambhota, to India, thus initiating centuries of contact with major centers of Buddhist scholarship there (Dreyfus, 2003; Van Schaik, 2013). In the 8th Century, another Tibetan King, Trisong Detsen, brought eminent Buddhist scholars, including Shantarakshita, abbot of Nalanda University, the seat of Buddhist scholarship in India, and the formidable guru Padmasambhava, to establish Buddhist practices and monasticism in Tibet. Emissaries also were sent to India to learn Sanskrit and translate Buddhist texts into Tibetan, resulting in production of the Tibetan alphabet and script orthographically adapted to the Tibetan language, as well as a formalized grammar (Shakabpa, 1984). Among their major effects on Tibetan society and culture, these innovations permitted translations of Buddhist texts with extraordinary fidelity to the originals in Sanskrit and Pali. A second major wave of Indian Buddhist scholars was ushered in during the 10th Century, whereafter Buddhism in India declined and was largely expunged by the 14th Century. Consequently, Tibet became the center of Buddhism in central Asia (Mongolia, Bhutan, Nepal, some of Russia and India) (Vleet, 2015). Many foundational Buddhist texts wiped out in India became available only in Tibetan under their monastic stewardship, and a flourishing Buddhism was institutionalized in Tibet to form a vast monastic establishment with distinctive schools, scholastic lineages, and practices that generated the rich corpus of Tibetan Buddhism (Snellgrove, 1995; Kapstein, 2006).

Active outreach by Tibetans also advanced development of a powerful Tibetan medical tradition, *Sowa Rikpa*, by recruiting input from major traditions elsewhere [(Gyatso, 2015), *p.* 105–8]. The Tibetan king, Songtsen Gampo, invited eminent medical practitioners from India, China, and Persia to share with local clinicians and distil their knowledge into texts that formed a comprehensive compendium of disparate medical systems (Tsultrim and Dakpa, 2009). A century later, Trisong Detsen famously brought prominent physicians representing three major medical traditions–Indian, Chinese, Graeco-Arabic–for an international conference (Gyamtso, 2017). Thus, evolution of Tibetan medicine drew upon medical knowledge and practices from India, western Asia, China, and its own indigenous shamanic traditions, while it also proceeded in close conversation with evolving Buddhist thought about the body, perception and affect, ethics and karma (Gyatso, 2010; Ga, 2014).

From these roots, Tibet emerged over centuries as the leading heir and guardian of the classic Indian Buddhist tradition and holder of a sophisticated medical system with widespread influence (Kapstein, 2006). The Chinese invasion and occupation of Tibet truncated this history by 1959, with an intent to destroy Tibetan culture (Shakya, 1999; Shakabpa, 2010). Ironically, the takeover also created a Tibetan diaspora that prompted global dispersion of Tibetan Buddhist monastics who fueled widespread interest in the tradition's highly developed ideas and practices (Zablocki, 2017). The Dalai Lama, head of the Gelug lineage and of the Tibetan government in exile until 2012, became a global figure engaging in teachings, conferences, and humanitarianism (Puri, 2006). Reciprocally, the Tibetan Buddhist community encountered novel systems of thought including western science. Out of personal interest, the Dalai Lama pursued decades of dialogue with western scientists and concluded that, in many significant respects, Buddhism and western science share common purposes and complementary perspectives (Dalai Lama, 2004). Consequently, the introduction of western science in Tibetan monastic education was inspired by his vision for comprehensive science education at Tibetan monastic universities which would foster informed engagement by his community. Once again, a Tibetan head of state charted a course of cultural outreach, this time by bringing in scientists to share knowledge and modes of inquiry.

Boundary Crossing in Monastic Science Education

The engagement of Tibetan Buddhist monastic education with western science commits to a dynamic evolution of its established community of practice. Although Tibetan history provides strong positive precedents for benefits of cultural outreach, the present initiative raises interest in whether and how it might succeed. Social science insights about processes of boundary crossing offer concepts and frameworks to address these questions, in terms of key mediators: boundary objects, boundary spanners, and mechanisms.

Boundary Objects in the ETSI

Boundary objects serve as powerful engines for boundary crossing by mediating iterative cycles of situated learning that generate social structure bridging communities of practice (Wenger-Trayner and Wenger-Trayner, 2015). From its inception, the ETSI invested heavily in co-production of boundary objects to scaffold monastic science education. These included the series of bilingual primers on each of the target disciplines written by teams of scientists and translated by Tibetan translators. This required *de novo* creation of a Tibetan science lexicon, because the relevant terms were absent in that language (see details in Samphel et al., in this issue). Both ongoing processes have taken years and involve intense collaboration between and among scientists and Tibetan scholars. The summer science sessions held annually during the 12 years of pilot and roll-out phases also were co-produced by teams of scientists who created written curricula and then taught it in India, together with Tibetans who translated written materials as well as in-person lectures and activities. All worked to revise materials iteratively across successive years of implementation. Cumulatively, 418 faculty were sent to India during the 6-years implementation phase alone, and annual monastic student enrollment reached 1,500 by conclusion of that phase. Moreover, by this time all three participating monastic universities had built and staffed science centers with teaching and research facilities.

In sum, by completion of the roll-out phase in 2019, a wealth of boundary objects (bilingual books, online science curricula and teaching materials, a rapidly growing Tibetan dictionary of science, and monastic university science centers) had been co-constructed through the concerted efforts of both monastic and science communities.

Boundary Spanners in the ETSI

As the previous section implies, the ETSI involved many active boundary spanners in the Tibetan monastic and western scientific communities. Within the monastic community, premier among these was the Dalai Lama himself who paved the way and prompted the initiative, even participating as inaugural speaker at the 2005 annual Society for Neuroscience meetings. Two of his close associates, Geshe Lobsang Tenzin Negi at Emory University and Geshe Lhakdor at Library of Tibetan Works and Archives in Dharamsala, India, work tirelessly for monastic science education, raising awareness, funds, logistics, and institutional involvement in both the U.S. and monastic communities. Identification and training of monastic students to spearhead science education was built into ETSI: the two cohorts of monks who participated in the pilot phase had been selected as strong scholars and potential leaders in monastic science education. Many of these went on to become science teachers, translators, and program leads at the monasteries and elsewhere. In addition, funding from the Dalai Lama Trust created the Tenzin Gyatso Scholar program that brings successive cohorts of monastics to Emory for 2 years of intensive science training. These Scholars have become central figures in the roll-out of monastic science education and its transfer to the monasteries themselves. Then there are the Tibetan science teachers and translators in India and the U.S. who are building the science lexicon, translating texts, and mediating direct exchanges between Buddhist monastics and scientists.

A flourishing literature by those engaged at the boundary of Buddhism and science includes books by the Dalai Lama himself (Dalai Lama, 2004), scientists who trained in Buddhism [e.g., (Wallace; Revel and Ricard, 1998; Dreyfus, 2003; Varela et al., 2016)], and scientists who have taught Tibetan Buddhist monastics (Impey, 2014; Eisen and Konchok, 2018). We have heard little from the monastics themselves [but see (Eisen and Konchok, 2018)], particularly from the monastic students. This likely will change as more reports emerge from diverse sources (see other articles in this special issue), and this report contributes to representation of the monastic community in ongoing discourses about engagement between Buddhism and science. Moreover, recent studies in boundary crossing emphasize the importance of all members of the community, of social dynamics, relationships, and the individual point of view. A review of change in higher education identified the need to go beyond structure and leadership to consider values, preferences, and goals that drive actions and relationships of participants (Kezar, 2014), while study of research-practice partnerships has identified the importance of graduate student perspectives (Wegemer and Renick, 2021).

We recognize that boundary crossing is dialogic, reciprocal, and evolves through time. The above background sections aimed to provide framing on cultural outreach and engagement with science by the Tibetan Buddhist monastic community historically and in the ETSI. In the present report we focus on perceptions and attitudes of monastic students in the ETSI program. After all, students are the crux of education. Although they are decisive factors in success of any program of learning, their voices are too seldom heard.

Study Aims

Our goal in this study is two-fold, first to identify attitudes and expectations about implementing science education among students in the Tibetan Buddhist monastic community, and second, to assess the bases for potential success of this project of cultural outreach from assessment of cultural frames and learning mechanisms for boundary crossing among Tibetan Buddhist monastic students. To address these aims, we use qualitative analysis of survey data collected at the early formative stage of the program in 2009 (Time 1) and focus groups, audio journal recordings, and interviews collected 10 years later, in 2019 (Time 2), after the full science curriculum had been implemented in the monasteries. Thematic analyses of Time 1 survey responses probe for initial presence of shared cultural affordances (attitudes, values, modes of thought and learning) related to engagement with science. Application of the Akkerman and Bakker boundary crossing framework to focus group, audio journal, and interview data gathered at Time 2 evaluates prevalence of the four boundary crossing learning mechanisms, namely identification, coordination, reflection, and transformation (Akkerman and Bakker, 2011). Throughout, we include quotes from the monastic students to illustrate and interpret our findings, and to give primary voice to the Tibetan Buddhist monastic community: after all, engagement with science is *their* project. Note that monastics are highly articulate; any roughness of quotes in English is due to translation.

METHODS

Participants

Monastic students enrolled in science education at the monasteries are adult learners with a well-developed cognitive frame and are already scholars themselves. They enter the science curriculum after completion of at least 10 years of Buddhist study and 3 years before starting exams for their advanced *geshe* degree, and thus have a deep grounding in Buddhist scholarship. Their ongoing Buddhist studies and monastic duties occupy much of their schedule, such that science education diverts time and attention from these demands.

Time 1. Respondents comprised 32 monastics in the first cohort enrolled in the ETSI program, including 28 monks and 4 nuns; age mean 32.8 ± 5.3, range 20–42 years; birthplace: Tibet 72%, 22% India, 3% Nepal, 3% Bhutan. They were advanced

Buddhist students and scholars nominated by their home institutions and selected for both enrolment in the pioneering phase of developing formal science curriculum for monastic education, and to act as leaders in science learning in their monastic community. All were pursuing formal Buddhist studies at monastic universities or institutions, having completed 16.2 ± 4.7, range 9–26 years of formal Buddhist education, excepting 2 monks who had completed advanced monastic degrees. Participants varied in previous science exposure in workshops or short courses, averaging 2.5 ± 2.9, range 0–9 prior experiences.

Time 2. Participants comprised 15 monastic student volunteers from Drepung and Gaden Monastic Universities who either were interviewed individually (n = 4) or completed an audio journal (n = 11). Seven of the audio journal group further participated in a focus group. Participants spanned the entire 6-year monastic science curriculum, from first- (n = 6), second- (n = 1), and third-year (n = 5) science students to graduates of the initiative (n = 3). All were male (monastic universities are exclusively male), ages 28–37 years, and in the 18th–23rd year of Buddhist studies. They had varied degrees of experience with summer intensive science sessions and/or year-round classes at the monastery. Participants differed in attendance at pre-monastic schools, with five out of seven focus group members having received formal education before joining the monastery and the other two beginning their education within the monastery school. Hence, this very small volunteer sample was somewhat diverse but unlikely to be fully representative of monastic students at all participating monasteries.

Preliminary focus groups. At the outset of ETSI in 2008, four focus groups were held to discuss science education and relationship to Buddhist views with 19 members of the first ETSI cohort whom senior monastics also had identified for parallel participation in a leadership program. All also participated in the Time 1 survey.

Procedures and Data

Time 1. In June 2009, at the start of the neuroscience segment for their second year in the summer pilot program of ETSI, students enrolled in the first cohort completed a written structured open-ended survey of attitudes and expectations about science, specifically neuroscience, and its relevance for them. Responses were written in Tibetan and thereafter translated to English by professionals fluent in Tibetan and English who also translated in ETSI classes. For the present analysis, two of the authors (ACK and CMW) coded responses to the following questions in the survey: "Why study neuroscience?", "What can science discover that Buddhism cannot?" and "Might they collaborate?" The first question was coded on two dimensions, subject matter (mind/consciousness, brain/nerves/senses/transmission) and intellectual interest (knowledge/understanding, relevance or comparison to Buddhism), while the other two were coded for content (nothing, material evidence, common interests, collaboration/complementarity). Content of a response might be coded on more than one dimension. Coders had high agreement for identifying codable chunks (99%) and good agreement for coding by category (93%). Disagreements were resolved through consensus.

Time 2. In December 2019, after the roll-out of the science curriculum in the monasteries was completed, seven monastic students participated in a 2-h focus group discussion about science education at Drepung Monastery conducted in English and Tibetan and co-facilitated by two of the authors (KMG and TL, also a Tibetan-English translator). Two days after the focus group, audio journal prompts were sent to 11 monastic student volunteers, including the seven in the focus group and another four students who were not able to attend the focus group. Audio journal prompts were posed in English and Tibetan both in writing and verbally. Student responses were approximately 5 min long, spoken in Tibetan, and collected over several days. Four volunteers from the first-year science class (n = 201) participated in the individual structured interview. Individual interview, focus group, and audio journal prompts (See **Supplementary Material S1–3**) span a range of topics including attitudes about science before and after exposure to it, impact and relevance of learning science, and comparison of Buddhism and science.

All recorded materials (interviews, focus groups, and audio journals) were transcribed for coding on references to boundary crossing learning mechanisms. The long narrative formats required a more complex analysis than the brief survey responses at Time 1. We used a thematic analysis approach (Braun and Clarke, 2019) to analyze the qualitative data (127 statements from 15 students). TL, RW, and KMG generated initial definitions of each learning mechanism using (Akkerman and Bakker, 2011) with minor adjustments for cultural appropriateness. ACK completed an initial coding; each statement was coded as reflecting one or more mechanisms or as Other (not applicable). CMW conducted a coding consistency check (Thomas, 2006) using the same codebook. ACK and CMW then reviewed any disagreements and came to consensus on a final codebook (definitions in **Table 2**) and the coding of all statements. Further peer checking involved coding the interview transcripts and later meeting to discuss and justify themes and text segments. Coders had good overall agreement (81%) and good agreement for coding by category (82%). Intercoder agreement increased the reliability of our interpretations, despite having only two researchers involved in the data analysis process (Creswell and Crewswell, 2017). Codable material contributed by participants varied widely: mean number of codable comments per person was 8.3, range 4–23.

RESULTS

Here we first present findings related to each of the two study aims, namely to identify cultural frames, attitudes, and expectations regarding implementing science education in the Tibetan Buddhist monastic student community, and to tap presence of learning mechanisms for boundary crossing among students once the program was rolled out. We report coded material with quotes from 2009 to 2019, complemented by

TABLE 1 | Initial attitudes about engaging with science, particularly neuroscience.

Frequencies represent a count of responses that used a related word or concept (n of respondents = 32)

Domain	Response	Count	Example
Why study neuroscience?			
Subject matter	mind/consciousness	15	*"To know about the relationship between cognition and consciousness." "To find the absolute relation between neurons and consciousness."*
	brain/nerves/senses/transmission	16	*". . . to know about internal functions of the body and also the transportation of information from the body to the brain." ". . . to see how our brain functions and how it controls our body, . . ."*
Intellectual interest	knowledge/understanding	19	*"Neuroscience is the only subject which comes nearest to what its already taught in Buddhist text, especially on the functioning of the sensory organs and how to recall and retain memory and so on. To understand better on these issues from the modern explanation I study neuroscience."*
	relevance or comparison to Buddhism	13	*"There are certain issues that is contradicted while many others that is complemented in Buddhism from science, so to know these things I study neuroscience."*
What can science discover that Buddhism cannot?			
Discovery	Nothing	11	*"As told in Buddhism there is nothing that Gautama Buddha didn't know and he didn't practice." "There is nothing that science can find and Buddhism cannot. But what ever they find could be different from each other."*
	material evidence	19	*"Science has been able to discover all those external knowledges and tools which Buddhism cannot." "Science can discover on the external physical things . . ." "Science works on external world while Buddhism focuses on the internal mental level."*
Might they collaborate?			
Discovery	common mission or subject	16	*". . . might help us in understanding how consciousness arises and so on." ". . . science alone cannot solve all those questions on mind so they can help each other mutually." "reduce suffering"*
	collaboration/complementarity	30	*"Yes they have to collaborate because it is beneficial to both." "Buddhism has been able to provide many fields for neuroscience to work on and at the same time, the findings from them have been able to provide a platform for Buddhism." ". . . science brings out the empirical findings while Buddhism answers these more logically."*

few select quotes from 2008 focus groups. Because 2008 transcripts are partial and all participated in the 2009 survey, only quotes particularly illustrative of themes documented in the coded material are included.

Time 1. Cultural Frames and Initial Attitudes Among Monastic Students Toward Science Education

Monastics endorsed the value of a firm foundation in Buddhism before studying science. As one student observed: ". . . we normally think that science and religion [are] very different and are contradictory. . . . First we need to know our own religion so we can analyze how science is and then we can define if they are contradictory." Although Buddhism and western science are distinct traditions, we asked whether there might be cultural conditions in Tibetan Buddhist monastic culture that support boundary crossing and cultural outreach with equanimity toward their possibilities for generating internal change if potential benefit is perceived.

Why Study Neuroscience?

Students' survey responses cited both subject matter and intellectual interest as prime motivators for studying neuroscience (**Table 1**). They highlighted the overlap in objects of inquiry for Buddhism and neuroscience, although the purposes of inquiry differ. Buddhist theory and practice aim clearly to understand operations of the mind and consciousness as well as perception and the senses (Dreyfus, 1997), because: "ultimately the mind is the root of everything that's there in the physical world and beyond." Indeed, "The most important characteristic of mind is to be able to engage with unlimited number of objects and when this engagement is guided through a right path then it leads to understanding of infinite knowledge." Hence, monastic study and discipline aim systematically to cultivate deep understanding and mental training so that "by knowing the mind and mental factors, one should be able to remain calm" and develop most fully the mind's ability "to engage with any object and also improve or develop infinitely".

A majority of survey responses expressed interest in learning specifics about how the brain and body function, and their relationship to consciousness. Buddhist texts provide detailed accounts of sensory perception and cognition, and relations of cognition to behavior, but mechanistic accounts of neurons, neurotransmission, and brain function are novel. Thus, study of neuroscience may help "understand better these issues from the modern explanation" with a view toward further understanding mind if neuroscience can help track "the absolute relation between neurons and consciousness." Allied with monastics' intellectual curiosity and interest in new knowledge from science, was a frequently emphasized intent to compare and contrast scientific accounts with their own Buddhist-informed understandings in order to evaluate and sharpen those understandings. For instance: "To see how neuroscience and Buddhism compliment and contradict each other, especially on mind and mental processes."

Similar to monastic practices of extensive debate to hone understanding of Buddhist thought (Dreyfus, 2003), study of scientific material and critical scrutiny in juxtaposition with a monastic's current views may provide grist for development of those views toward a more accurate understanding of things as they are. "So, in this way science can answer many questions for monks in Buddhism and it is important to have an understanding why and what can be the difference and we can think about these results." Monastics expressed confidence that their years of grounded training in logic and critical analysis of concepts and evidence would be powerful tools for engaging effectively with science and deriving benefit if it were there to be found: "In Buddhism there are various texts or tenets that [are] used where we have to use our logic and our minds to study, and in science also we have to use our minds, and so it is helpful to have a chance to learn science and we can correlate them."

What Can Science Discover That Buddhism Cannot?

Responses reflect Buddhist epistemology that buddhas are omniscient; hence, the principled reply by a third of respondents was: "Nothing." (**Table 1**) Given a view of the mind's capacity for infinite development and knowledge if properly trained, as the Buddha's was, it is in principle possible to know anything science can discover, and much more. Thus: "Science is a minute physical entity and a part of Buddhism". That such enlightenment is excruciatingly rare, opens wide a window for critical engagement with new forms of knowledge that advance the core Buddhist project for enlightenment, for one's own or other scholars' understandings may be limited or faulty. This critical stance is a core tenet of Buddhism: "And the Buddha said you don't have to take my words out of respect for me. You need to check it out for yourself and if you find something wrong, then don't accept it, even if it is said by me. So that is the backbone of Buddhism so there is no reason for not learning science." This stance informs monastics' view of the relationship of scientific to Buddhist knowledge: "There is nothing that science can find and Buddhism cannot. But whatever they find could be different from each other."

Consequently, although a third of respondents said nothing new could come from science, two-thirds endorsed the value of material evidence that science produces with sophisticated methods and tools, citing the scientific focus on the external or material physical world in contrast to the Buddhist focus on internal or immaterial mental realm. These positive responses highlighted that Buddhism and science share a common mission to reduce suffering along with common objects of inquiry. Scientific evidence was valued also because it might advance Buddhist scholarship, for instance it ". . . might help us in understanding how consciousness arises and so on."

Might They Collaborate?

Given their views on complementarity of foci, methods, and goals in science and Buddhism, nearly all respondents roundly endorsed the potential value of collaboration between them (**Table 1**). None expressed perceived threat from studying science *per se*, although competing time demands were an issue; rather, monastics expressed excitement about the intellectual stimulation, valued the potential for advancing their own development, and foresaw a possibility that new questions and insights might emerge from such critical engagement. As one of them noted: "They have to collaborate because neuroscience explanation is highly related or closely related to the understanding of consciousness. So the knowledge from both sides have to come together and maybe we will find a third area to work on."

Time 2. Boundary Crossing Learning Mechanisms in a Community of Practice

Coded statements from focus group, audio recorded responses, and interviews in 2019 yielded counts of how frequently monastic students invoked boundary crossing learning mechanisms when talking about their interactions with western science education. Monastics often spontaneously alluded to these learning mechanisms, suggesting that conditions for boundary crossing in Akkerman and Bakker's schema were being met (**Table 2**). Specifically, each of the four domains appeared in a substantial portion of coded statements, and at roughly the same frequency. By contrast, endorsement frequencies for subdomains under each of the four mechanisms varied substantially. Responses invoking specific mechanisms in each learning domain are characterized below.

Identification

Monastic students expressed identification in their othering statements ("contradictory to the Buddhist understanding of how the cause give rise to effect") and legitimating coexistence ("this makes sense and reasonable") comments. Reflexive thought related to legitimating coexistence was observed as frequently as othering statements in transcripts (**Table 2**). This may be due to the monastic commitment to egolessness and robust training in analytic thinking that reflects on interdependence.

Coordination

Coordination was observed most frequently in remarks regarding communicative connection, here construed as effective communication ("Before I learn science, I never thought math is needed." "After learning science . . . complete new knowledge."). Frequencies for some mechanisms within the domain of coordination varied widely (**Table 2**).

Reflection

Respondent's statements robustly demonstrated reflection, representing the views of western scientists on their own terms (perspective making; "Through engagement with science, I know the nutritional value of those foods that I have been ingesting.") and were only somewhat less likely to empathically consider scientists' views with Buddhist views in mind (perspective taking; "I realized that there is comparative learning between the science and Buddhism.").

Transformation

Evidence of transformation was observed in confrontation of views ("I am learning Buddhist student, we can say that we disagree with evolution theory. We say it is fate which brings the animal to this environment."), and to an even greater extent in the recognition of shared problem space ("These mathematical expression seemed to have some relation to Buddhist concept such as bodhicitta mind."). Interestingly, hybridization or integration of different bodies of knowledge is mentioned as often as is confrontation, again related to respondents' Buddhist training both to critically engage any given view and to seek resolution through examination ("I think if we collaborate two

TABLE 2 | Domains and related mechanisms involved in boundary crossing between communities of practice.

Domain frequencies represent a count of utterances that referenced any constituent mechanism in that category. Mechanism frequencies represent number of utterances referring to that mechanism. (respondent* n = *15; utterances coded* n = *127)

Domain	Mechanism	Definition	Count	Example
Identification		Apply personal and conceptual work to encounters between traditions	80	
	Othering	Characterize one tradition in terms of another, based on distinctive features and points of difference	39	*"If one is really dedicated to finding the truth through the scientific method it takes a lot of time and a lot of effort. . . . Buddhist study itself is very rigorous, so there is no time to take part in this kind of research."*
	Legitimating coexistence	Validate and accommodate both traditions	41	*". . . if we Buddhist and we Biology science just* [complement] *each other also develop in this world . . . many, many beneficial."*
Coordination		Cultivate means and conditions that promote effective cooperation among diverse practices, even if consensus is absent	74	
	Effective communication	Exchange impactful information, as noted in before/after comparison by respondent	40	*"Before I learned, all I understand about visual perception is from the Buddhist text. . . . After learning science, light reflection playing role . . . photoreceptor playing role . . . signal transduction . . . perception. Complete new knowledge."*
	Translation	Clarify distinct views and concepts, in both literal and subjective senses	11	*". . . though the term "living being" is being used by scientists and Buddhist people, the way the term is defined in each is different. . . . In Buddhism, when we talk about living beings we are talking about . . . having consciousness. . . .On the other hand, when we talk about science, living beings have these seven characteristics. . . . Initially, it was challenging to accept this."*
	Increase boundary permeability	Facilitate fluid cross-boundary action and exchange	18	*". . . if the scientists and the Buddhists each have their own methods of analyzing an object, if these two methods of analyzing the same object can come together then it could create something more. And called this bridging."*
	Routinization	Normalize cooperation and habituate to exchange	5	*"Whenever there are new terms in science or English, he always takes notes. He takes a small notebook in his pocket. He always carries that small notebook. Whenever he has chance, he always read, take it out from the pocket and he read and learn some new words."*
Reflection		Understand and articulate both practices and reflexively deepen understanding of each	76	
	Perspective making	Articulate personal understanding of a concept or domain	43	*"Science is a study using physical material. Evidence-backed experiments that are not driven by religious dogma or national, patriotic feelings. . . .Totally unbiased and experimental way which is supported with a lot of evidence. That is a method of experiment. Evidence."*
	Perspective taking	Empathize with others' views by reflexively considering one's own	33	*"The way science and Buddhist text talked about experiment are something we could compare. . . .*[S]*cientist use previous finding by the different scientist to examine with re-experimentation. . . . Likewise, the previous . . . realization in Buddhist text are not to be taken granted but rather subjected to thorough investigation using experiment."*
Transformation		Effect substantive change in both communities	85	
	Confrontation	Consider a conceptual or pragmatic gap that requires both parties to evaluate existing practices	22	*After learning a bit about brain (CNS and PNS), and comparing that with Buddhist, we say it's consciousness, but neuroscience may not. However, neuroscience did lot of research on the brain . . . those are fact, but if all body and everything is controlled by just brain, this is little difficult to accept.*
	Recognizing shared concerns	Identify a mutual concern to tackle cooperatively	28	*"Science is . . . based on experiments using physical materials; now . . . science is going to inner science which talks about mind. This is where Buddhist science comes into play."*
	Hybridization	Combine elements to realize new insights or practices, on the personal or cultural level	20	*"These mathematical expression seemed to have some relation to Buddhist concept such as bodhicitta mind. I think there might be able to prove it also using math. Saw huge potential in helping society."*
	Crystallization	Integrate substantive changes in the practice	0	Not observed

(Continued on following page)

TABLE 2 | (*Continued*) Domains and related mechanisms involved in boundary crossing between communities of practice.

Domain frequencies represent a count of utterances that referenced any constituent mechanism in that category. Mechanism frequencies represent number of utterances referring to that mechanism. (respondent* n = *15; utterances coded* n = *127)

Integrity maintenance	Maintain core elements of each tradition while cultivating hybridity at the boundary	5	*". . . scientist give credit to the pioneer and father of those knowledge...even though those finding may not hold true. . . . I find it interesting as from Buddhist student. It actually motivated me to find the sources in my field even more than ever."*
Continuous joint boundary work	Sustain engagement to achieve ongoing exchange	10	*"Nowadays everyone is everyday living with the science. Unlike earlier time where people did not have scientific knowledge. Finding the truth takes twenty or 30 years. It's a long process to reach the truth."*

field, it might help the society"). Analogous to routinization, crystallization involves a substantial shift in existing practice resulting from boundary crossing and exchange and was not observed in our data. Routinization and crystallization must be established through upstream processes of accommodation on personal and institutional levels.

Boundary crossing to science is barely approaching the point where there is a perceived need to maintain uniqueness of the monastic community of practice. Rather, the importance of time for science studies and the need for sustained boundary work and exchange were endorsed by the monks ("So that it is very important that you [western science teachers) come here and we all just, you come here." "It's a long process, to reach the truth."). Respondents pointed out that monastic universities have invested in science centers that act as sites for this work, highlighting the value of these boundary objects.

Non-Linear Progression in Boundary Crossing Between Communities of Practice

Our observations indicate that boundary crossing mechanisms operate dynamically in a process that develops through time (Risien and Goldstein, 2021). Mechanisms related to early stages of boundary crossing were frequently mentioned, while those related to long-term change (crystallization, integrity maintenance, continuous joint work) were mentioned rarely or not at all. The ETSI program is young. Introduction of the science curriculum began in summer 2014, and many participants in this study had begun science studies just recently. One might expect identification, especially othering, to prevail in early boundary exchange. Further, one might expect reflection only after an extended period. Interviewee responses suggest that importance of each mechanism may vary with duration of exchange (translation: "Initially, it was challenging to accept this . . ."; continuous joint work: "Nowadays everyone is everyday living with the science."), community characteristics (othering: (Buddhist study itself is very rigorous . . .")), and ability to establish common ground (boundary permeability: "And I think these two schools have to collaborate because even though there are some minor differences but there are many complementing areas in both.") Translation and boundary permeability were especially salient when monks experienced challenges to effective science communication in the classroom or with accommodating science studies in their other studies and commitments. ("If one is really dedicated to finding the truth through the scientific method it takes a lot of time and a lot of effort. Even if they (monastic students) want to do that kind of research, they are unable.") Statements from students in the monastic community of practice reflected a view of science education as a work in progress, both for themselves and at institutional and cultural levels.

DISCUSSION

The present study responds to the historic decision by the Tibetan Buddhist monastic community to introduce western science in their monastic university curriculum. This move resonates directly with similar acts of cross-cultural outreach that had tremendous impact in Tibetan history, including one that fueled the formation and rise of Tibetan Buddhism and another that founded Tibetan medicine. In each case, Tibetan leaders acted as culture entrepreneurs who reached out internationally to secure input from the top thinkers and practitioners in a field. Tibetans thereafter actively worked with the input to develop their own rich and effective traditions of thought and practice, and demonstrated leadership, agency, and creativity in charting the course of Tibetan culture in the vital domains of spiritual and physical well-being.

Daring as the decision to introduce western science might appear, our data from monastic students identified a range of factors that support its soundness, including cultural conditions, mechanisms that facilitate boundary crossing by communities of practice, and a cascade of effects that devolve from both of these. Initial cultural conditions and attitudes identified at Time 1 include perceived overlaps in subjects and methods of inquiry. Monastics highlighted their interest in mind, body, all sentient beings, cosmology and matter that overlap with areas of scientific inquiry. They also appreciated scientific methods of rigorous inquiry, skepticism, repeated observations, independent inquiry and empiricism, and minimization of bias that were similar in spirit if not in detail to Buddhism. Further, they valued the empirical information from science that illuminated structures (e.g., neurons), mechanisms (e.g., neurotransmission, sensation) and processes (e.g., memory, vision) that were hitherto unknown or explained in different terms in Buddhism. Yet they also emphasized the need for critical evaluation of this information as they would any evidence in Buddhism, *via* reflection and debate.

They further noted that such evaluative processes would provide grist for monastic study and debate comparing and contrasting accounts in science and Buddhism. Lastly, the theme of complementarity ran through student responses, including notions that interaction of Buddhism and science might produce new questions and possibly open new modes and fields of inquiry.

Monastics' view that the purview of science was narrow compared with the expansive one in Buddhism may contribute to the absence of perceived epistemological threat or concern about dominance from science in remarks by these Buddhist scholars. Yet, while a third of respondents said there was nothing that science could learn that Buddhism could not, they consistently endorsed the possibility of seeing the same things differently, demonstrating again their openness to complementarity and potential collaboration.

Prevalence of boundary crossing mechanisms among participants' remarks in 2019 provides robust evidence both that these mechanisms are in operation, and that their importance in the process of boundary crossing changes through time. Monastics spontaneously and frequently expressed mechanisms of identification, coordination, reflection, and transformation. That maintenance of community integrity and joint work rarely appeared and crystallization not all, strongly suggest that the process was in its early stages. Although these observations would need to be tested in a larger, more systematic and representative sample, it is suggestive that the boundary crossing schema was fully manifest in these data, and encouraging that boundary crossing mechanisms were so actively present.

Taken together, the data suggest four inferences regarding reception of science education among monastic students, discussed in the following sections.

Core Elements of Buddhist Thought and Practice Provide Strong Affordances for Open Engagement With Science Despite Differences in Traditions

Across time, monastic students persistently reported reasons for engaging with science, both early and late in the process of developing and implementing science education for monastics. They emphasized shared objects of inquiry; note, however, that our 2009 data largely concerned neuroscience which they considered directly pertinent to their focus on mental phenomena and mind-body relations. They also expressed intellectual interest in new knowledge as tools for thought and inquiry to expand their current Buddhism-based understandings, and anticipated the possibilities for comparing material in the two traditions.

Monastics pointed to many areas of Buddhist epistemology and monastic training that prompted these attitudes. We highlight four here. First is an emphasis on independent observation and testing over received wisdom, which they see as having parallels in scientific methods: "methods adopted by the Buddhism and the science for investigation, they are similar. In science people don't believe what everyone says, they have to check it for themselves and they need to do the experiment for themselves and see the reasons so then they believe what other is saying." Second, is a rigorous search for truth with the aim to minimize bias and a willingness to discard what is refuted. One student cited the Buddhist maxim that ". . . one who does not believe in truth is not a wise man. You have to go with the truth no matter who you are. No matter who you are, if you are away from the truth, you are wrong. Any concept that is not true must be eliminated so as in science we can establish truth so they are parallel." Correspondingly, 10 of 31 responses to a 2009 survey question about the purpose of science specifically cited "truth" as a goal, and thus congruent with Buddhism.

Third is a set of powerful intellectual affordances cultivated in monastic training, comprising the vast Buddhist literature allied with rigorous training in logic and critical inquiry to both deploy and interrogate that literature. Thus: "Science is much, much easier than Buddhism. In Buddhism we have so much to memorize. . . . you have to think a lot and use your logic. The teachers in Buddhism don't give you the answer and you have to find it yourself. There is no possible way to find answers from the physical things like books." Through this process, monastics master the resources and skills to take on arrays of new ideas and information. "It is a part of our tradition in Buddhism that whatever we learn we debate with others and we try to convince others with reason and logic and textual information, so this is in our tradition when we learn science. . ." Fourth is a set of cultural affordances grounded in a view of radical uncertainty prompted by tenets of inherent ignorance and illusion with the aim to eliminate both, combined with an aim to incorporate interdependence and impermanence as existential givens. Given such profound challenges, monastics know the work will take a lifetime and more, and are open to valid means for speeding their path toward enlightenment: "It's a long process to reach the truth." Cooperation is essential: for instance, "Debating is key to understanding Buddhist concepts."

Monastic Students Recognize These Affordances as Situated in a Distinctively Buddhist Frame

This point was consistently supported by the monastics' written responses and verbal observations. As could be seen in the previous section, monastics framed the bases for engagement with science in terms of the concepts, skills, and methods of Buddhism. One might expect that they would do so at this early stage, but importantly, they clearly see grounds for engagement as located within their own tradition rather than as requiring them to step outside or discard elements in their community of practice. Right intention is key: "Nothing [is] wrong with science by nature so it is up to practitioners to use it in the right way or wrong way. It is the same way for religion also. It can be misused or used [for] the betterment of living beings. . ."

From a Buddhist perspective, the scope of phenomena tackled by science is relatively narrow. Monastics view Buddhism expansively, as affording the means, or path, to attain a complete account of phenomena across all time and space. Someone who eliminates problematic mental states such as anger or desire, and removes cognitive distortions by expunging the illusion of permanence, selfhood, and attachment to conventional reality, then may realize absolute truth and omniscience. Monastics regarded the purview of science as related to a significant but minor portion of Buddhist pursuits, as follows: "I believe that science is a part of Buddhism, Buddhist concepts. When we talk about Buddhism we can make it into 3 stages, the physical level of whatever is truth, then the path which is a different thing and then the result of that path is called the Buddhahood. When science is concerned, it is concerned about the basic truth of the physical thing." Monastics agreed that discovering those "basic truths" about physical realities is important for well-being, but they also point out, and scientists would certainly agree, that they do not address everything that matters. Buddhism has developed tools for exploring realms that science does not or does poorly: "In science you need material things but in Buddhism you have your own equipment, your hand and your mind."

This Buddhist Frame Makes Space for Critical Engagement

Monastic students use this space to advance their Buddhist understanding, which frames the project as a positive gain for monastics as individuals and as a community. Monastic student responses largely endorsed this point, albeit wiMonastic students use this space to advance their Buddhist understanding, which frames the project as a positive gain for monastics as individuals and as a communityth a caveat. Given the Buddhist presumption of inherent ignorance and the commitment to mental transformation, monastics were highly attuned to possible limitations or distortions in their knowledge and understanding. One wrote that: "The most important is to know what you don't know already." Alongside their formidable body of Buddhist knowledge, training, and skill, they readily entertained the need and possibility for further learning and development. They appreciated when learning science transformed their understanding of basic relevant phenomena such as sight, light, or matter: "Before I learned, all I understand about visual perception is from the Buddhist text. . . . After learning science, light reflection playing role . . . photoreceptor playing role . . . signal transduction . . . perception. Complete new knowledge." Hence, they expressed that scientific knowledge and methods might contribute to their understanding of important issues, although only after close critical scrutiny. For instance, monastics repeatedly noted the lack of an adequate account of consciousness in neuroscience and considered theirs as a very different view (". . . science is unable to integrate the physical material with consciousness." ". . . when we talk about consciousness it is a different thing, a different level." ". . . also in Buddhism we can go to the minute level. Science doesn't go down to this level."), yet remained open to finding value in scientific attempts to understand it. One monk intended to ". . . understand these [physiological] mechanisms and simultaneously to compare this information with that taught in Buddhist texts on consciousness and subtle wind energy." In such endeavors, they plan to use the tools developed in Buddhist training to critically evaluate science and selectively integrate insights deemed valid and useful, rather than simply appropriating or rejecting it. ". . . I learnt about the way science do experiment, it's very systematic and the benefit of studying science is that we get new ideas. It reinforces the way we study Buddhist philosophy. The ways science and Buddhist text talked about experiment are something we could compare. By doing so, it helps us."

Hence, respondents regularly observed that learning science offers potential benefits for their Buddhist pursuits. ". . . the scientists and the Buddhists each have their own methods of analyzing an object, if these two methods of analyzing the same object can come together then it could create something more. . . . Is it possible to have this kind of research?" Note that monastics considered their engagement with science as being on an at least equal footing, and generously pointed out that ". . . science alone cannot solve all those questions on mind so they can help each other mutually."

Nevertheless, student willingness to find space for critical engagement is mitigated by constraints and possible areas of conflict around pursuing science studies that monastics pointed out both in 2009 and even more in 2019. As noted earlier, monastics' studies are demanding and their schedules very full. Study of science necessarily takes time and attention away from strictly Buddhist pursuits. One said that: "Basically, I don't have much time for . . . learning science. Because I have Buddhist philosophy classes. I have to go to lecture and debate and prayer and all of this." Another shared: ". . . if [a student] is not interested it is not useful, I think. . . . First we must understand the benefit." Buddhists regard attainment of a human life as a rare, precious, and all-too-brief opportunity to work toward enlightenment. Distracting from well-marked routes on the path may seem a hindrance unless one sees the benefit in terms of advancing one's own progress or, better yet, pioneering a path that may yield benefits for others in future. After all, the ultimate purpose of pursuing a Buddhist path is to benefit all sentient beings, and western science may or may not advance it.

Nested Factors Operate in Boundary Crossing by Monastic Students

Prevalence of disposing conditions at Time 1 and boundary crossing mechanisms at Time 2 suggest there are nested factors that might foster Buddhist monastic student engagement with science and ensure benefits for the monastic community and beyond. In the first of these nested factors, student responses invoked core elements of Buddhist thought and practice as providing strong affordances for open engagement with science, starting with common interests and values. They consistently linked Buddhist training to their interest in, appreciation of, and expectations for engagement with science. For instance, they regarded their Buddhist grounding in independent observation, dedication to rigor, and emphasis on testing and verification from multiple vantages as directly applicable to, and sympathetic with, scientific values and methods. Additionally, they considered the skills in Buddhist logic, debate, critical inquiry, and reframing of personal understandings that they developed through monastic training, as resources to be used in their studies of science. In particular, the cultivated openness to intellectual challenge and to new information relevant to their Buddhist pursuits added to the pleasure and stimulation that many reported experiencing in science studies. The new information that scientific research and technology could provide on subjects of common interest was valued by many of our monastic interlocutors, stimulated by Buddhist recognition of ignorance and sensitivity to the possibility that one's own knowledge and views are limited or erroneous: "There can be things that an individual Buddhist practitioner cannot find yet it can be discovered through scientific processes."

The second set of factors scaffolds the first: monastics grounded their engagement with science within their Buddhist scholarship, recognizing the aforementioned affordances as situated in a distinctively Buddhist frame. Note that they cast the interests, skills, and approaches that animate their science studies in Buddhist terms. Their openness to scientific knowledge, ideas, and methods was grounded in Buddhist values and epistemic practices. The sense that science might amend or advance but would not compete with or displace Buddhist scholarship arose from a view of Buddhist knowledge as all-encompassing whereas that of science as limited to material, measurable things, a relatively narrow purview. This widely shared view was succinctly captured here: "There is nothing that Buddhism cannot find but science has." This places science within the wider Buddhist enterprise, and contributes to the consistently expressed sense of openness and absence of threat or defensiveness about engaging with science. As one monastic wrote: "There are more reasons to continue this collaboration than not to continue it."

The third set of factors scaffolds the previous ones, for monastics' comments indicated how Buddhist teachings and practices open space for critical engagement with science that monastics use to advance their Buddhist understanding. For example, one observed that "findings done by neuroscience in a very empirical manner fill in some of those missing parts in Buddhism." Indeed, right intention to benefit Buddhist knowledge and understanding itself can justify engagement with science. Monastics' drive to improve their understanding was allied to a primary Buddhist goal to benefit others. "... I think it will be beneficial to all sentient beings if we can bring together neuroscience and Buddhist science to try and find out the relationship between meditation practice and behavior of the neurons. How far it is beneficial."

These stances frame the project as a positive gain for monastics as individuals and as a community, as well as for their wider mission universally to reduce suffering. "At this moment, Buddhism have been able to provide many fields for neuroscience to work on and at the same time, the findings from them have been able to provide a platform for Buddhism."

In sum, the attitudes, observations, and motivations expressed by monastic students engaged in learning science manifested a set of cultural conditions, mechanisms for exchange, and nested dynamics in Buddhist thought and practice. These illuminate grounds for the Tibetan Buddhist monastic community's engagement with science and augur for its success. In this case, "success" would mean enrichment of Buddhist thought and practice through an open-ended developmental process driven by the monastic community toward as yet undetermined but likely path-breaking outcomes in future. Within social scientific understandings of boundary crossing by communities of practice as a complex, multilayered enterprise, the individual merits more attention. We hope that insights generated by attending to monastic student voices in this instance illustrate the value of that approach.

Limitations and Future Research

This qualitative study is based on data collected with different goals in mind and thus has substantial limitations of design, interpretation, and generalizability. First, different methods of data collection were used at Time 1 and Time 2, which precludes direct comparison over the 10-year period. The entire class was surveyed at Time 1, but Time 2 was a pilot study involving volunteer participants in the focus group and audio prompt responses, with a very small and self-selected sample not necessarily representative of Tibetan Buddhist monastics. While it is intriguing to see that the boundary crossing schema was reflected in our 2019 data, we emphasize that the small sample and post-hoc nature of the analysis require future work with a larger representative sample to see if the schema remains useful. Given our observation that boundary learning mechanisms vary over time and operate synergistically, such a study might recruit equal numbers of students from each year of the science curriculum. Alternatively, a longitudinal study following students through all years of science study could directly observe boundary crossing learning experiences over time. Further work on boundary crossing could probe variation among monasteries and Schools in Tibetan Buddhism and track institutional change through time.

Future work would require creation of survey and interview questions specifically designed to investigate presence and direction of boundary crossing learning mechanisms, and increase generalizable understanding of dynamics in communication across communities of practice. Formal methods of instrument construction and translation should be used. The written survey instrument used at Time 1 was translated directly from English to Tibetan and neither back-translated nor subjected to cognitive testing (Van Ommeren et al., 1999). Similarly, translation of responses at both times was direct only. At Time 2, prompts were communicated to students by English-Tibetan translators, raising the possibility of inconsistency in definitions, conceptualization, and interpretation of terms. Equivalence is difficult to achieve even when questions are generated and responded to in the same language and similar cultures (Limeri et al., 2020), more so when multiple languages are involved.

Contributions of this study to the literature on boundary crossing are limited in several respects. Most prominently, only views of monastic students are represented. Members of the rest of the monastic community (faculty, administration, other monastics) should be engaged in future studies. The same is true of the western scientific community. Although the latter already are more well represented in publications, they also are thinly represented in empirical social science research. Second, boundary spanners and particularly boundary objects are known to play crucial roles in boundary crossing (Carlile, 2004; Thomas et al., 2007; Leung, 2020). We refer to them at the outset, but work with them is needed to build a rigorous understanding of this case of boundary crossing. There is some urgency, as time is passing and the project moves forward, suggesting that the moment to tap starting conditions and processes is now.

Lastly, the process of Tibetan monastic outreach to science would merit rigorous long-term cultural analysis, particularly of models and schema (Shore, 1996; Weller, 2007). Our data were not designed for this and were unsuited to such analysis, but our array of coding-based findings suggest this is an important area for research, perhaps by the monastic community itself. Impact of science education through time, its distribution and evolution within Buddhist scholarship, and many other questions about cultural and institutional change would merit investigation. The aspirations of monastic education diverge sharply from those of traditional western education. Tibetan Buddhist monastic education equips students to pursue a path of self-transformation toward attaining enlightenment, a process usually taking many lifetimes. In traditional western education, learning and earning degrees often are directly tied to career prospects and financial security. Hence, study of the project to include science in monastic curricula could yield profound, novel insights into education as well as culture change and adaptation.

Implications

Engaging across difference has emerged as one of the great challenges of the 21st Century even as globalization and media have removed barriers to communication. Increasing numbers of communities and even nations have suffered displacement to life in diaspora, as have many Tibetans and much of the Tibetan Buddhist community. Incorporation of science education in Tibetan Buddhist monasteries is a tremendous cultural project that directly affects the next generations of monastics and will ramify through future monastic scholarship and discourse. Our findings from monastic students identify shared features of Tibetan Buddhist thought and practice (e.g., critical thought, openness to change, cooperation) that both motivate and support this work, and may serve as inspiration for other forward-looking efforts in crossing boundaries by communities of practice, even very established ones. Proactive outreach to science by Tibetan Buddhism may serve as a case study for a middle way that combines cultural adaptation with maintenance of tradition as a path to cultural survival or, more than that, flourishing and growth. We close with the Dalai Lama's words on this matter:

> *"Our community shall not remain as it is. There will be changes. . . . The knowledge of science will be instrumental in the preservation, promotion and introduction of Buddhism to the new generation of Tibetans. Hence, it is very necessary to begin the study of science."* (Dalai Lama, 2000).

> *"A note of caution is called for, however. It is inevitable that when two radically different investigative traditions like Buddhism and neuroscience are brought together in an interdisciplinary dialogue, this will involve problems that are normally attendant to exchanges across boundaries of cultures and disciplines."* (Dalai Lama, 2005).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion 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 the Institutional Review Board of Georgia State University. 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 in 2009: CW, and in 2019: KG, TL, RW, and GG. Data coding and analysis TL, RW, KG, CA-M, AK, and CW Writing: CW and KG 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.2021.724114/full#supplementary-material

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