


# Cultivating educational adaptability through collaborative transdisciplinary learning spaces

Aishwarya Ramachandran<sup>1</sup>  · Meg Schwellnus<sup>2</sup> · Derek Gladwin<sup>3</sup>  · Ryan Derby-Talbot<sup>4</sup>  · Naoko Ellis<sup>5</sup> 

Received: 1 August 2023 / Accepted: 19 December 2023

Published online: 02 January 2024

© The Author(s) 2023 

## Abstract

Empowering students and scholars to effectively address complex societal challenges frequently entails embracing unconventional pathways to foster transdisciplinary (TD) education. This empowerment is further facilitated by collaborative efforts supported by the TD experience. This paper examines one such initiative: a student-centered, experimental design of a TD doctoral pilot program for environmental sustainability at the University of British Columbia, a large, research-intensive public university in Canada. In this study, we documented shifts in participants' development and assessed the impact of TD collaboration conditions on the educational design process. The findings indicate that engaging in collaborative TD experiences yields substantial pedagogical benefits, introducing novel opportunities for design and experimentation. This TD space appears to offer conducive conditions for students and faculty to more effectively navigate adaptive and innovative contexts within higher education. Pedagogical experimentation of this nature provides insights that are challenging to derive from theoretical speculation alone, offering potential pathways for today's learners and educators as they confront complex societal challenges.

**Keywords** Transdisciplinarity (TD) · Transdisciplinary education spaces · Collaborative learning · Educational design · Higher education · Complexity education

## 1 Introduction

Higher education programs are calling for training that draws on design and implementation to address increasing complex issues in the 21st Century. How might higher education evolve to exhibit greater ingenuity and nurture adaptability in professional activities (e.g., [42], Sec. 4)? Transdisciplinary (TD) approaches to research, instruction, and learning can play an important role in engaging with complexity—a science and theory of interconnected systems that often brings uncertainties, paradoxes, and contradictions—because they are problem-focused, foster collaboration and participation, and require evolving methodologies [41]. Moreover, TD approaches are particularly capable of dealing with multiple truth claims and diverse societal contexts and policies [33], as well as fostering collaboration among academic experts and knowledge builders from different disciplines [14].

✉ Derek Gladwin, derek.gladwin@ubc.ca; Aishwarya Ramachandran, aishwarya.ramachandran@ubc.ca; Meg Schwellnus, meg.schwellnus@gmail.com; Ryan Derby-Talbot, rdt@deepsprings.edu; Naoko Ellis, naoko.ellis@ubc.ca | <sup>1</sup>School of Kinesiology, University of British Columbia, Vancouver, BC, Canada. <sup>2</sup>University of British Columbia, Vancouver, BC, Canada. <sup>3</sup>Department of Language and Literacy Education, Faculty of Education, University of British Columbia, 3031 PCN, 6445 University Blvd, Vancouver, BC V6T 1Z2, Canada. <sup>4</sup>Deep Springs College, Deep Springs, CA, USA. <sup>5</sup>Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, BC, Canada.



Beyond inter- and multi-disciplinary research approaches, TD research facilitates emergence of new disciplines and the co-production of knowledge along with experts and practitioners, among other stakeholders, resulting in a more profound understanding and impact on complex societal challenges [39]. The direct connection and collaboration between researchers and practitioners (i.e. stakeholders) lead to intricate research processes requiring specific practices and competencies and orientations in TD research [10]. Competencies are often considered specific, measurable skills and knowledge, while orientations can be seen as broader attitudes and approaches that influence how people engage with learning and education. Cultivating TD competencies and orientations, such as intellectual risk-taking and creative inquiry, can be viewed as essential skills for individuals seeking to become transdisciplinary practitioners [2]. And yet, institutionalizing structures and strategies have been slow to develop TD programming, and discipline-dominated systems of higher education continue to be sustained [3].

This paper studies a student-centred experimental approach to developing a collaborative TD doctoral (PhD) pilot program focused on the complexity of environmental sustainability at the University of British Columbia, a large, research-intensive public university in Canada. The study follows the experience of two undergraduate and four graduate students (the “cohort”) as they work with faculty members for six months to collaboratively design (i.e., co-design) features and develop resources (including reading lists, team building activities, facilitation strategies) for the future TD PhD pilot program. Rather than placing the onus on the cohort to establish a new TD doctoral program or components of it, the invitation extended to them was to collaboratively engage with one another, faculty, and workshop leaders in the experimental design of a TD space from which a PhD program was built later. This initiative sought to serve as a valuable resource for the creation of future programs and the education of the cohort as learners. Re-examining disciplinary boundaries in the context of TD research acknowledges the considerable contributions that undergraduates, along with graduate students, can offer to the process by virtue of their valuable insights.

In the TD space, there was not the opportunity for direct engagement with an external stakeholder, a common feature of TD research; instead, we focused on co-designing possibilities for a future cohort to undertake such interactions. Our findings suggest that such a collaborative TD experience offers significant pedagogical value to participants, opening new possibilities for design and collaborative experimentation. Such a TD space provides conditions under which students (and faculty) are more effectively able to implement adaptive and innovative contexts in higher education. We are interested first in understanding how different experimental spaces for TD collaboration might affect participants, so that such learnings inform and suggest new approaches to TD and higher educational development. This kind of pedagogical experimentation can offer insights difficult to obtain from theoretical speculation alone and offers possible paths forward for today’s learners and educators taking on complex societal challenges.

## 2 Background and review

Many approaches to TD continue to evolve, as seen extensively in Augsburg [2] and Lawrence et al. [25], including an overview of the definitions, characteristics, phases, and forms of knowledge associated with TD research. In general, approaches often vacillate between valuing TD as either or both unities of knowledge and social engagement [25]. Since approaches to TD are more accepted than definitions [11, 20], we found a unifying overlap within TD literature: the ability to bring together various disciplines, experts, and researchers to collaborate on complex issues, which are also called wicked problems, that often elude disciplinary approaches, some of which establish partnerships with external stakeholders. We are particularly compelled by the notion originating from Piaget [31], but extended by [27, 28], that considers TD as across, through, and beyond disciplines, which is the co-creation of spaces that transgress restrictive and/or siloed disciplinary boundaries. We use TD in this paper as a recognizable approach to situate and transgress the disciplinary boundaries of the educational experimental design space of our study.

TD spaces are flexible and potentially transformative as they provide opportunities, otherwise rare in university settings, not only to expand how students and faculty learn, but also to encourage the development of new competencies and orientations, including diverse knowledges, interpersonal and team skills, and the ability to comprehend and tackle complex societal challenges [23]. Bovill et al. [5] similarly suggested that various graduate attributes are conducive to collaborative TD research, including an awareness and appreciation of disciplinary differences and thought styles among collaborators and collective learning [7]. This may involve the in-between and difficult to articulate spaces for sustainability learning [40], creating new collaborative learning spaces [35], or finding ways to bridge TD within sustainability education spaces [16]. TD spaces challenge and negotiate the assumptions of the dominant university culture by providing opportunities for students and faculty from often divergent disciplines to interact and collaborate on a common

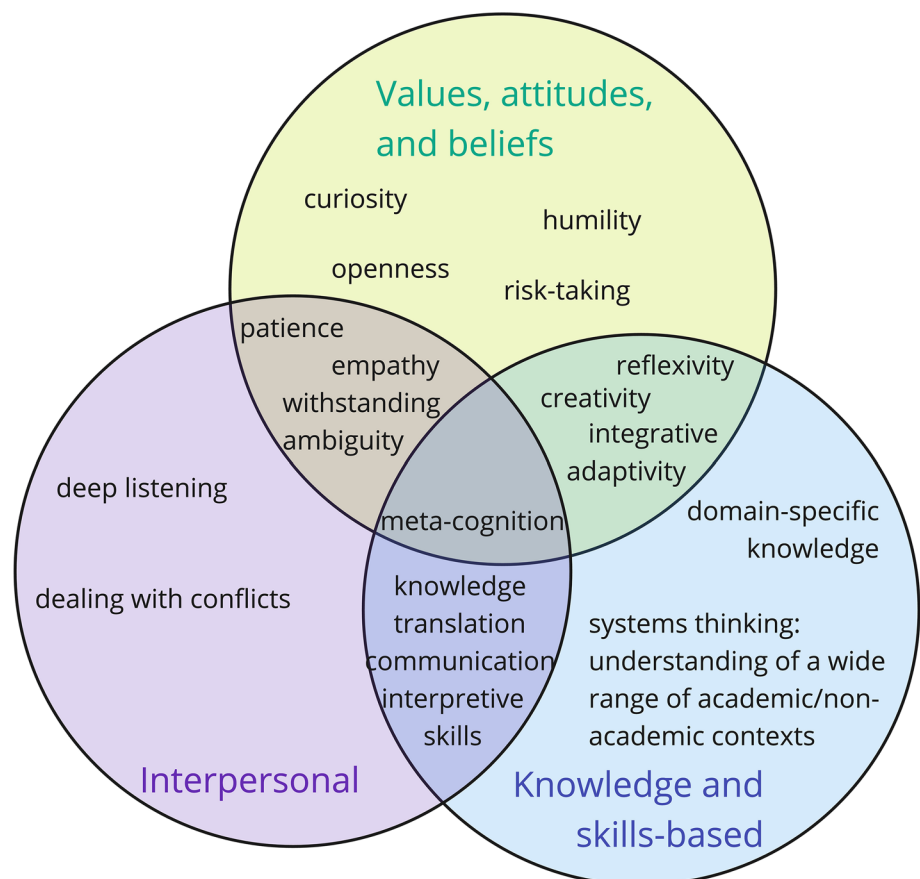
problem, concept, or idea that is of mutual interest and may be approached from a wide range of perspectives [24]. Such spaces also allow for symmetries of unknowing to occur [12], contributing to the cultivation of doctoral education that has the capacity to nurture diverse disciplinary identities and potentially extend beyond them [17]. Ultimately, TD spaces offer a kind of epistemic diversity and pedagogical inclusivity that contrasts with siloed disciplines and reductive cognitive models of normative educational approaches.

There are a wide range of ways programs might facilitate the development of a TD orientation, such as drawing on values, beliefs, attitudes, knowledge and skills, and behaviours that are conducive to collaborative TD research [37]. For example, Kemp and Nurius [22] identified how TD might involve four interconnected orientations: (i) critically engaging, reflecting on, and integrating one's own and others' disciplinary languages, perspectives, and worldviews; (ii) collaborating with researchers and stakeholders from a wide range of disciplines and sectors; (iii) communicating and understanding research beyond one's discipline; and (iv) conducting research using theories, concepts, and methods from multiple disciplines. Similarly, Uhlenbrook and de Jong [38] described the necessity of cultivating both disciplinary depth and boundary-spanning orientations and competencies in a professional holistic model. In a previous publication [32], some of the authors of this paper developed a three-category framework of TD orientations, which has been adapted below in Fig. 1. TD orientations include some competencies, as well as worldviews, attitudes, and values, which encompass holistic ways of engagement.

### 3 Research study

This study emerges from several years of conducting design-based research (DBR), imagining and working to develop collaborative TD spaces in higher education. Beginning with a graduate seminar to bring diverse faculty and students together around topics pertaining to environmental sustainability and climate change, several opportunities to fund and engage in iteratively building frameworks to support collaborative TD research and teaching have allowed us to continually learn and adapt. This process follows DBR, which is based on design-thinking and is a methodology,

**Fig. 1** Transdisciplinary orientations (adapted from Ramachandran et al. [32], with permissions from authors)



according to Anderson and Shattuck [1], used by educators with the aim to impact, transfer, and translate educational research into practice. As O'Neill [30] explained, educational design research can inform the methodology—i.e., the efficacy and learning of the process was examined and applied during iteration.

As depicted in Fig. 2, an iterative process of designing, testing, evaluating, and reflecting is repeated at multiple scales (i.e., during program development, as well as curricula building). This paper reports on the “co-design phase” (summer 2022) of Fig. 2 working with the cohort (six students/co-designers) and faculty to design and test contents. Following this phase, the collaborative TD PhD program cohort (nine PhD students and nine faculty members) engaged in a pilot year (2022–2023). In the context of this study, the TD space serves as an academic learning environment for cultivating competencies and experiences, preceding engagement with knowledge communities (i.e., external stakeholders), which are often characteristic elements of TD research. Ultimately, we are learning at these various stages and continue to improve the program for the future.

Our research focuses on the learning experiences and development of TD orientations among the cohort. The co-design phase was set up to bring together students and faculty to explore the space of possibilities within TD. This can be considered an initial phase of design, which, as Botero et al. [4] demonstrated, are spaces for potential circumstances that allow new designs to emerge. The students involved in this project were hired as research assistants (RAs) for a design period of six months. Their main responsibilities involved attending biweekly discussion sessions to experience the TD space together and working with faculty input to curate a list of course readings and class activities to include in the upcoming pilot program. Because the faculty members involved with this project would be guiding students in the subsequent TD PhD pilot program, they were encouraged to use this design period to also test some of their instructional materials with the cohort, as well as to seek feedback from them about how to better introduce and teach TD research orientations. As such, the cohort was clearly informed there would be no assessments or any form of evaluation during the six months.

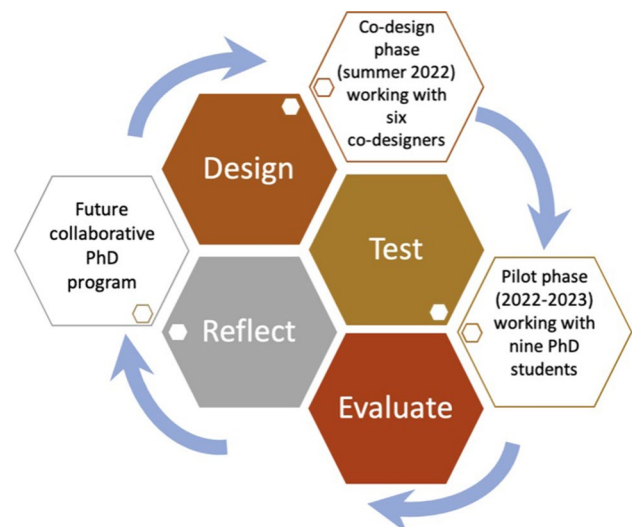
While TD orientations and design-thinking methodology were introduced, discussed, and encouraged, we also, as the leading faculty, wanted to co-create conditions for TD collaboration. We emphasized the importance of working collectively by dissolving the comforts of disciplinary identity into the mess of TD approaches, which led to the following research questions:

What were the orientations observed while the cohort was in a collaborative transdisciplinary space?  
How might we foster conditions for co-creating collaborative transdisciplinary spaces in academia?

## 4 Methods

This study included six students (the cohort) and nine faculty members. Students were selected from a pool of 134 applications, based on team interviews of 17 short-listed applicants that were divided into four groups. They were selected for their potential to be open-minded, think collectively under pressure, and adapt to various disciplinary

**Fig. 2** Phases of iterative design in a design-based research process. The solid hexagons represent the design process, while the outer hexagons show the related periods/phases taken to build the TD program



**Table 1** Background of participating students and faculty

Student areas	Faculty areas
Electrical Engineering (Year 3 BAsC)	Forestry
Chemical Engineering (Year 4 BAsC)	Language & Literacy Education
Public Policy & Global Affairs (MA)	Chemical Engineering × 2
Arts & English (MA)	Resource, Environment & Sustainability × 3
Language & Literacy Education (PhD)	Civil Engineering
Chemical Engineering (MASc)	Educational Studies

**Table 2** List of topics covered during the co-design sessions with faculty

Co-design session topics
Introduction: working collaboratively on the “bandstand” through improvisation and cultivating decolonial futures
Innovators compass: introductory activity for TD scholarship
Transdisciplinary theory, practice, and education
Unpacking our disciplinary worldviews: an exercise in research reflexivity
Transdisciplinary research: from conception to results
Integrated assessment of climate change
Critical ingredients and theories of change
Transdisciplinarity in action
Evaluation methods for guiding transdisciplinary research
Co-design work: onboarding activities; annotated reading list
Bandstand redux: Improvising in a system
Final session: facilitated session designed by the cohort

expertise. Students and faculty backgrounds are listed in Table 1. In-person and online sessions (through videoconferencing) were held 2–4 times/month, where faculty would spend time discussing different aspects of TD research and education with the cohort (topics listed in Table 2) and respond to any readings and educational materials they had assigned for that session. The sessions required the cohort to engage in group-brainstorming activities and encouraged faculty members to test some of their TD instruction materials with the group and solicit feedback. The sessions also complemented group activities and discussion among the cohort and sometimes faculty, and group work around TD research topics pertaining to environmental sustainability. TD was presented by numerous faculty members to demonstrate the range of ways it might be conceived, practiced, and approached. The cohort were also asked to investigate and then respond to the collected definitions and approaches in Fam et al. [11], which also included numerous TD literature.

Two additional RAs, who were not participants of the cohort and are co-authors of this paper, were hired to collect data for the study. Both RAs had prior experience with doing qualitative research. Consent to participate and publish anonymous data was obtained, based on the Behavioural Research Ethics Board (H21-02363) at the University of British Columbia from both the faculty members and the cohort to collect data. Sessions were recorded while notes were taken on participant interactions and behaviour. The cohort wrote short reflections at the end of each session that were also used as data. Three anonymous surveys at the beginning, middle, and end of the co-design period, focus groups, and individual interviews were conducted with faculty members and the cohort.

The anonymous surveys asked the cohort to provide a code name they would use for all three surveys to allow for paired analysis of their responses over the study while maintaining anonymity (as required by the research ethics approval). The focus groups (2 sessions of 3 students each with each student participated in one) and individual interviews were semi-structured, hour-long interviews, with the questions pertaining to the students' perceived experiences of the collaborative sessions, their high and low points, and any additional content they wished to discuss. The focus groups were conducted in the middle phase and the individual interviews were completed at the end. These data were collected by the RAs and kept in secure digital storage.

The RAs used NVivo software to analyze surveys, interviews, focus groups, and written reflections with an inductive, open-coding approach [34]. Findings were grouped from this initial coding process into categories or themes based on

similar substantive content [6]. As data were collected via multiple channels, the RAs divided up coding each interview, focus group, reflection, and anonymous survey at the end of the co-design period. The RAs subsequently deliberated on the initial set of codes individually identified, refining the language and consolidating the codes through a collaborative discussion. They revisited the data once more, searching for common or recurring themes that emerged consistently across the various sources of data. The RAs compiled a list of representative quotes, some of which were paraphrased for concision, sourced from multiple data points to substantiate and support each identified theme. This approach proved valuable as thematic analysis is not tied to a specific theoretical tradition, allowing its application across various ontological and epistemological positions. Subsequently, we collaboratively expanded upon these themes, examining them through the lens of TD orientations as outlined in Fig. 1.

#### 4.1 Results and emerging indicators

Based on the analysis of collected data, three major recurring themes emerged throughout the responses in the focus groups, interviews, surveys, and reflections: adaptive interpretations of TD spaces; perceived student and faculty roles; shifting dynamics of the cohort. In the following results that showcase the emerging indicators, the RAs triangulated data from the interviews, surveys, and reflections to provide an integrated approach reflecting the TD space, leading to garnering holistic understanding [26].

##### 1. Evolving understandings and interpretations of transdisciplinarity

During the biweekly sessions, there were many opportunities to define and approach TD and consider the kinds of orientations it might require. The cohort discussed the real or imagined boundaries of their own and others' disciplines, and how they could learn from and with one another to collectively address complexity. The cohort reported confusion over diverging definitions and interpretations of TD offered by faculty members and guest speakers. Because the faculty-led sessions often began by defining and re-defining the concept of TD, one student suggested the importance of agreeing on a common definition of TD at the outset. The cohort acknowledged, conversely, that sticking to just one definition may have predetermined and limited how they approached and experienced their group work. From the faculty point of view, the introduction of various approaches to TD was intentional and reflective of the diversity and adaptive nature of TD research.

Towards the end of the co-design period, most of the cohort reported that "the abstract definitions you read about TD work won't get you there because other people in your team will use other definitions than you." They refined their interpretations of TD through the experiences of productive engagement and tensions with one another. Some students found that each time they approached a challenge, they also had to change how they framed their thoughts and thus their definition of TD.

The shift in how students considered and defined TD reflected the orientations they were developing as seen in Fig. 1 and Table 2. Initially, being exposed to diverse descriptions of TD in a wide range of academic literature prompted them to reflect upon and value specific attitudes and qualities, including openness, humility, risk-taking, and creativity. With more experience through the process, the cohort valued clear communication of ideas, goals, values, and concepts coming from different fields, particularly in a jargon-free manner. Being able to patiently explain one's "perspective and view and understanding others" was described as a "good practice" by the cohort for work-life professionalization.

The tensions that arose while working on deliverables reiterated that reflexivity, deep listening, and empathy were crucial to TD, as was a willingness to be "wrong" and letting go of one's assumptions about others' knowledge or skills. One student in the cohort noted, for example, how at the beginning of the co-design period, they were quicker to criticize or correct each other. Another explained, "if I felt someone was going the wrong way, I would kind of say something. Later I was like, well, you know, maybe it's good to just listen and see where it's going." Towards the end of the co-design period, they noted they had learned to be more "vulnerable" with each other, in service of addressing tensions, conflicts, and differences during collaboration. Through the variety of sessions the cohort experienced, they were able to explore uncomfortable, vulnerable moments. In one of the final sessions, a student reflected that "overall I think we respected each other and were inclusive of each other's ideas."

##### 2. The persistence of perceived student and faculty roles



The fundamental aim of establishing an experimental TD space is to facilitate a shift for both students and faculty, encouraging them to move beyond their conventional roles as learners and instructors and instead engage as collaborative partners. This involves a convergence of responsibilities and a reduction in hierarchical distinctions. However, stepping in and out of one's firmly entrenched professional and personal identity while working on a collaborative project remains challenging, particularly when the collaboration dissolves disciplinary perspectives. This process, in turn, tied powerfully back to one's student or faculty role and led to feelings of uncertainty around perceived outcomes and program structure.

Even though the intention behind developing this co-design experience aimed at cultivating experimental TD spaces without a concrete set of deliverables, the cohort frequently commented on the lack of structure in both the faculty-led sessions and the group tasks. They reported that the open-endedness of the sessions and group work made them feel uncomfortable and unsure about how they could best contribute to the co-design process. The cohort also indicated that they expected more instruction or guidance about the nature of their role and the deliverables. This was a recurring response throughout, despite the cohort being reinforced that capturing their experience and reflection of the process was the critical part of the study.

The cohort reflected how they tended to rely on their disciplinary tendencies, such as methods, styles of writing, familiar theories, etc., because it felt easier than having to develop an entirely new approach. One student observed some of the inherent paradoxes of TD research: the "open-endedness of some of the tasks almost closed a lot of doors." The cohort's desire to know how their work on potential deliverables would be evaluated by faculty or how it might be used in the subsequent TD PhD pilot program also resulted in members going from a "safe space to just ponder and explore ideas to more of the traditional 'fear-of-failure' mindset." These concerns remained throughout the co-design period even though faculty members often communicated that the students would not be evaluated or assessed for their participation or contributions.

There were also different levels of motivation within the group. While some students were able to flow with unstructured approaches to collaboration, others felt stuck when working without clear outcomes and assessments. One student discussed the challenge of not being evaluated, working through "nervousness" around their assumptions about expected outcomes, particularly when they wanted to "earn our money" from this position. In the last few weeks, some of the cohort noted a distinct lack of feedback from faculty members about their collectively developed resources and materials, which led to them feeling disengaged from the TD spaces. One cohort member "noticed that [openness of work] mentality sometimes when we're doing the collaboration," where not knowing "what the expectations were" reduced the value of the deliverables.

Much of the cohort expected faculty members to build off each other's lectures, workshops, or discussion materials. A faculty member later iterated that from a "student's perspective it probably would have been better to have a continuing underlying theme in each of those sessions." When asked about how to address student concerns about the structure of the sessions, another faculty member pointed out the challenges associated with synchronizing the efforts of multiple faculty members across departments and disciplines, particularly with heavy teaching loads and other supervisory commitments throughout the academic year.

Some of the cohort also observed that certain faculty members similarly struggled to step outside of their role as traditional instructors and become collaborators. A few faculty members chose to organize their session in a more traditional lecture style, with one even conducting their session in a lecture hall. This, in turn, created difficulties for the students to work on their assigned group activity since they could not easily sit face-to-face with each other. One student reflected on how they "did not think that the room was very conducive to discussion" so, as a group, they "moved outside of the room" to feel more connected. This stands in contrast to an earlier session where one faculty member encouraged the cohort to split up into groups to discuss their disciplinary backgrounds and assumptions about them. Several students pointed out how this was a highly effective way to develop a deeper, focused understanding of their peers' disciplinary backgrounds as well as learning to clearly articulate the assumptions and approaches of their own backgrounds.

The cohort pointed out that highly moderated or controlled discussions could inadvertently discourage students from more openly sharing their ideas, suggesting that "the content of our discussion does not matter, because if it did, we would see it through, until no more follow-ups or questions can be added." They also acknowledged that such an approach could risk a single conversation going on "forever." Conversely, the cohort appreciated it when one faculty member decided to use their session to propose a new methodology they were working on, using student comments and feedback to actively make changes and amendments to it throughout the session. This had the effect of making it one of "the most engaging sessions", where "it really felt like the co-design group was being used to bounce ideas off of, and help sharpen a vision for the presenter."

### 3. The shifting dynamics of collaboration and developing orientations

The cohort initially exhibited considerable enthusiasm about the prospect of collaboration. When asked about how they perceived teamwork in TD, all the respondents claimed that collaboration was undeniably “integral” to, “at the heart/centre of,” or a “prerequisite” to such research. Reflecting on their experience engaging in a collective brainstorming and conceptualizing exercise during the beginning of the project, for example, one student said they thought the “beauty” of TD collaborative efforts emerges from group members sharing the similarities and dissimilarities in their individual thought processes and disciplinary knowledge. Overall, they articulated the importance of many values and attitudes-based competencies like risk-taking, epistemic humility, and knowledge integration/transformation, as well as communicative and interpretive skills.

An early sense of camaraderie was soon tested in the middle phase when the cohort was tasked with collectively preparing resources for the pilot (with guidance from the faculty). The cohort quickly began falling back on disciplinary certainty when undertaking this work. The fading of disciplinary identity, and the inherent feelings of inadequacy that arose out of this process, eroded confidence or certainty when working together. One student described the main challenge as being one of learning how to tackle the case in a “TD way.” The group had a “tendency,” as was communicated, “to divide [a complex issue] up into fields and then come up with solutions from each field separately.” This student also noted that the group relied on solutions using “discipline-specific” approaches and using “qualitative methods to try to integrate the work of the different fields.” Other students similarly relied on quantitative methods. The faculty’s intention was to place the cohort into a TD space where they felt the need to collaborate effectively. However, their tendency to work individually, as opposed to collectively, magnified their feelings of disconnection in this phase.

These epistemic and collaborative tensions, often associated with TD group work [18], brought an unexpected source of disconnection in week 18 when a faculty member leading the session examined the use of quantitative and qualitative methods. In this session, the cohort quickly split up into disciplinary factions between applied and natural sciences (quantitative) and the humanities and social sciences (qualitative). Student reflections that week articulated clear tensions among the cohort. Antagonistic feelings emerged for the first time in the TD space, in contrast with the curiosity and openness established in the first eight weeks, and were largely based upon disagreements about the perceived value of their disciplinary backgrounds and knowledge. For instance, one student reported being “frankly shocked” by some of the statements made by their peers about the importance and relevance of qualitative research. When they scheduled opportunities to collaborate on team deliverables during planned sessions after Week 18, the explicit tensions continued to exist. The cohort struggled arriving at a consensus of how to develop materials and resources for the future TD PhD pilot. They frequently disagreed about how to “best approach” dealing with a complex issue, which usually derived from their previous disciplinary experiences rooted in qualitative or quantitative frameworks.

Towards the end of the co-design phase, some members stated they had learned to create more space for other, quieter members of the group to vocalize their perspectives. One student reflected they began practicing “active listening/turn-taking,” as well as presenting their “ideas concisely and clearly.” Another who often felt like they struggled to manage their speaking time, “selectively” participated in group discussions, and listened more. Still another member noted the importance of using concrete examples when discussing disciplinary differences rather than resorting to disciplinary terminology or abstractions. The cohort noted that when the process of collaboration is unclear, as many TD spaces often are, it is “paramount” that group members have “interpersonal skills, communication, and respect” for each other. Moreover, they acknowledged that orientations and skills, such as patience, deep listening, and clarity of communication, would take time to develop and practice.

The ever-shifting dynamics of the TD space continued towards the end of the co-design period, where the cohort were encouraged to improvise in a system. The faculty came full circle and revisited the approach introduced in Week 1—being “on the bandstand,” referring to an improvisational jazz band, drawing on Harris [15]. The metaphor of the bandstand illustrates the necessity for participants to be fully present, actively listen to each other, and create space for diverse styles and contributors in a collaborative process, fostering TD orientations, as depicted in Fig. 1. Taking the time and space to collectively reflect on where everyone started and arrived, the faculty and the cohort revisited the ways we can play on the bandstand.

Two faculty members facilitated the final session for the cohort to collectively build a systems map of a complex issue around regional wildfires. The reflections of the cohort following this session underscored their experiences of both learning and unlearning practices and processes related to collaborative systems mapping—a pedagogical approach involving collaborative diagramming of connections on topics like wildfires. This learning occurred within the framework



of the jazz improv bandstand metaphor. Through their reflections in this TD space, a distinct narrative unfolded, diverging from the one previously shaped during the tense middle phase characterized by a tendency to gravitate towards disciplinary certainties surrounding qualitative and quantitative approaches.

One student stated: "I think overall it was our most 'bandstand' session that we had. People were able to demonstrate their improvisational skills as well as their listening through connecting and adding onto ideas." Many of the orientations gained over the co-design period manifested in reassuring ways. Another student reflected how the session allowed them "to show up free of assumptions and willing to produce something (i.e., ideas) even in the face of uncertainty." Another cohort member drew on previous TD language developed over the term: "It was chaotic and messy, but it was continuous, friendly, and accepting."

## 5 Discussions

Over the course of the study, the cohort refined orientations that were introduced at the outset and throughout the TD space, as seen in Fig. 1. Through collaboration, they learned to appreciate the importance of interpersonal perspectives, deep listening and clear, jargon-free communication, as well as patience, empathy, and respect for divergent views. They also displayed increased comfort with uncertainty, acceptance of perspectives, and holding space for group tensions, all of which indicated a higher degree of meta-cognition as observed through their individual reflections.

During the co-design period, it became evident that there was a discernible evolution in how the cohort comprehended and defined TD and its associated complexities, particularly through sustained collaborative efforts. Baptista and Klein [3] noted that providing a universal definition of TD continues to be a challenge, but also suggested that most definitions point to developing new understandings of or solutions to complex problems which cannot be handled from a single perspective. The ability of the cohort to assess, revisit, and refine their definitions, understanding of TD based on their ongoing experiences in the sessions and engaging in group work, pointed to the development of TD values and habits of mind, such as openness, intellectual creativity, a tolerance for uncertainty, and adaptability [29].

We also observed the tendency to fall back into disciplinary certainty influenced the collaborative experience. In a similar situation reported by Chan and Stacey [8], going beyond the engrained roles remained difficult without prior experience or training. The stickiness of student and faculty roles presented as obstacles to the knowledge integration and team cohesion central to TD spaces (e.g., [13, 17, 29, 32]). And yet, as Chan and Stacey [8] indicated, overcoming this stickiness is a "desirable difficulty" in engaging student as partners (p. 242). While embarking on a curricular co-creation experience, they noted how student empowerment, as well as feelings of frustration, and faculty vulnerability are interconnected in the process. Recognizing that the cohort emphasized challenges associated with disciplinary discomfort, we, as the researchers, also suggest that conditions for TD collaboration can be a generative, process-orientated space of learning. Reimagining and renegotiating TD spaces requires time to adapt (see Future Research below).

Our study documents the overall co-design process capturing the progression and dynamics of TD spaces. We consider the TD space to be supporting a co-creation process, leading to future TD research and education, which often includes stakeholder engagement. Such a space has become necessary in building orientations and experiences that ultimately provide greater stamina for the challenges of TD works. Part of this process involves recognizing and working through potential challenges for the participants. As observed by Horn et al. [19], there is early enthusiasm for collaborative TD work among students. It is not until students face the disciplinary differences, values, and assumptions that they uncover their "deeply rooted, persistent, and fundamental differences of epistemological and ontological beliefs" (p. 1964), which often block the process of becoming "epistemically adaptive." While open-ended brainstorming and dialogue can be useful in exposing students to the ideas and values around TD, it is not a substitute for highly involved, integrative collaboration. In our co-design process, for instance, the cohort's tensions that emerged over research methods were documented as tense and uncomfortable. And yet, this experience was essential in developing interpersonal, integrative, and communicative orientations among the cohort that emerged towards the end.

Upon deeper reflection of the process, we considered how sharing TD orientations more frequently may have helped the cohort better understand their roles and eased their discomfort in the messy process of TD spaces. For example, McGregor (2011) notes the zone of discomfort as an in-between space which involves going beyond easy answers, moving away from one's comfort zone, and staying engaged in ambiguity and new possibilities. In this sense, TD collaboration is inherently a way of un/learning in discomfort and experiencing the perception of failure as a process that mirrors the initial reason for incorporating TD into education and instruction—to navigate with the paradoxes, contradictions, and

uncertainties associated with complexity. Developing a TD space can invite students and faculty to show up in ways that honour the spaces in between and beyond subjects, people, and disciplines that remain uncertain and complex. For example, these spaces can provoke participants to see their identities and assumptions emerge from their own subjectivity, as the discourse across groups can dislodge them from their tacit assumptions and default understandings of the isolated groups. Studies in adult development suggest that individuals will often resist initiatives that risk hidden identities or assumptions which provide subconscious feelings of safety [21]. As Deslauriers et al. [9] pointed out, while certain kinds of active pedagogical experiences reward learners with better learning than traditional methods, despite the consequent challenges, learners may resist these at the outset.

The TD learning space reported here represents just one among several approaches to fostering collaborative TD experiences in higher education. The experimental space for TD collaboration has shown to support participants with exploratory, process-based experience that allows crossing disciplinary boundaries and co-creating potential avenues for adaptation and innovation. This TD space may nurture building TD orientations in participants which can be foundational in supporting future TD research of facilitating emergence and co-production of new knowledge along with others such as experts and practitioners. Ultimately, these TD spaces in higher education can lead to possible paths forward for today's learners and educators taking on complex societal challenges.

Moving forward, we seek to build strategies in TD spaces for students to navigate through this uncertainty and emerge with greater stamina and resilience. We also share, anecdotally, that the cohort presented their experience at a large national conference a few months after the co-design phase with great enthusiasm for the unique learning of this experience. In fact, three of the six cohort members who co-presented received an award for their presentation. Perhaps learning experiences continue to allow students to develop and transform beyond the designed TD space, which is not captured during this research period. Some of the faculty involved additionally experienced camaraderie in this process as a collective and gained the stamina required to embark on the next step of this project.

## 5.1 Limitations

The limitations of this study pertain to its narrow scope. As this is just one example of what a TD space might look like, it may not reflect other contexts without further adaptation. Another limitation was the imbalance of data collected from the cohort as compared to faculty members. While we had several sources of data from the cohort, including written reflections, interviews, focus groups, and surveys, we were only able to speak to faculty-student dynamics through participant observation, as well as through comments made by the cohort, and short interviews with some of the faculty members involved.

## 5.2 Future research

Our first research question aims to understand how TD spaces support the development of collaborative TD orientations, which are outlined in the Results and Emerging Indicators, and Discussion sections. The second research question considers what conditions foster the development of TD spaces in general. Addressing the second question, and building on the Results, we reflect on future research as evolving processes that may include:

- Process-orientated learning, as opposed to linear outcome-based modes of learning, is less common in academia. As such, care and support for the participants going through the process is helpful.
- There is inevitable tension that arises between the individual and the collective during the coming together phase. Fostering and holding space during this phase becomes an important practice. This may be done through creating paradoxical conversations (e.g., [36]) to encourage experiencing the discomfort of sitting with disciplinary diversity. In addition, holding space for ambiguity and experimentation in a collaborative group, while moving away from a default or safe knowledge base can be practiced through co-experiencing sessions, readings, etc.
- There is an opportunity for deep learning because of engaging with TD work. Perhaps highlighting that layered levels of tensions are necessary in transformational and relational learning experiences can ease certain discomfort during the process. Furthermore, acknowledging TD spaces as necessarily messy, which invokes feelings of inadequacy and results in discomfort, but also generates deep learning may support learners in this space.

## 6 Conclusion

Utilizing a design-based research methodology enabled us to experiment with the co-design phase, ultimately leading to the development of the Transdisciplinary (TD) Collaborative PhD pilot program. The experimental educational space created opportunities to experiment and learn in TD spaces, which included building stamina for the disciplinary uncertainty that emerged when re/learning about disciplinary mindsets and gaining confidence in showing up to the collective. TD spaces provide opportunities to explore alternative perspectives on learning conditions in higher education, specifically regarding TD orientations that necessitate dedicated time and space for design and development. Continuing to evolve in epistemic and ontological adaptability presents an ongoing avenue for growth, and based on our own experiences, we advocate for the design and implementation of future TD learning spaces in various educational contexts. In the face of complexities that society faces, higher education may create and apply process-oriented TD spaces to cultivate knowledge and orientations that equip students in navigating through challenges collaboratively.

**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by AR and MS. The first draft of the manuscript was written by AR and MS. DG and NE wrote the second and subsequent drafts with revisions and with guidance and help from RD-T. All authors commented on first version of the manuscript. All authors approved the final manuscript.

**Funding** This work was supported by the University of British Columbia Climate Emergency Fund.

**Data availability** Raw data included in this paper are not publicly available to preserve the privacy of participant responses as regulated by the Behaviour Research Ethics Board (BREB) at the University of British Columbia. These data are, however, available from the authors upon reasonable request and with the permission of BREB.

## Declarations

**Ethics approval and consent to participate** The University of British Columbia, Behavioural Research Ethics Board: H21-02363. Students' and faculty members' perceptions of TD programs at The University of British Columbia.

**Consent for publication** Consent to participate and consent to publish were obtained from all participants.

**Competing interests** No financial or non-financial interests are directly or indirectly related to the work submitted for publication.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

1. Anderson T, Shattuck J. Design-based research: a decade of progress in education research? *Educ Res.* 2012;41(1):16–25. <https://doi.org/10.3102/0013189X11428813>.
2. Augsburg T. Becoming transdisciplinary: the emergence of the transdisciplinary individual. *World Futures.* 2014;70(3–4):233–47. <https://doi.org/10.1080/02604027.2014.934639>.
3. Baptista BV, Klein JT. Institutionalizing interdisciplinarity and transdisciplinarity: collaboration across cultures and communities. Routledge. 2022. <https://doi.org/10.4324/9781003129424>.
4. Botero A, Kommonen K, Marttila S. Expanding Design Space: Design-In-Use Activities and Strategies, in Durling, D., Bousbaci, R., Chen, L, Gauthier, P., Poldma, T., Roworth-Stokes, S. and Stolterman, E (eds.). (2019) Design and Complexity—DRS International Conference, 7–9 July, Montreal, Canada. 2010. <https://dl.designresearchsociety.org/drs-conference-papers/drs2010/researchpapers/18>.
5. Bovill C, Cook-Sather A, Felten P, Millard L, Moore-Cherry N. Addressing potential challenges in co-creating learning and teaching: Overcoming resistance, navigating institutional norms, and ensuring inclusivity in student–staff partnerships. *High Educ.* 2016;71(2):195–208. <https://doi.org/10.1007/s10734-015-9896-4>.
6. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* 2006;3(2):77–101. <https://doi.org/10.1191/1478088706qp063oa>.
7. Brown VA, Lambert JA. Collective learning for transformative change: a guide to collaborative action. Routledge; 2012.

8. Chan K, Stacey P. Desirable difficulties and student-faculty partnership. *Innov Educ Teach Int*. 2022;59(3):242–52. <https://doi.org/10.1080/14703297.2020.1861964>.
9. Deslauriers L, McCarty LS, Miller K, Callaghan K, Kestin G. Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proc Natl Acad Sci*. 2019;116(39):19251–7. <https://doi.org/10.1073/pnas.1821936116>.
10. Djenontin INS, Meadow AM. The art of co-production of knowledge in environmental sciences and management: lessons from international practice. *Environ Manage*. 2018;61(6):885–903. <https://doi.org/10.1007/s00267-018-1028-3>.
11. Fam D, Neuhauser L, Gibbs P, editors. *Transdisciplinary theory, practice and education: the art of collaborative research and collective learning*. Springer; 2018.
12. Fischer G. Symmetry of ignorance, social creativity, and meta-design. *Knowl-Based Syst*. 2000;13(7–8):527–37. [https://doi.org/10.1016/S0950-7051\(00\)00065-4](https://doi.org/10.1016/S0950-7051(00)00065-4).
13. Fiore SM, Gabelica C, Wiltshire TJ, Stokols D. Training to Be a (Team) Scientist. In: Hall KL, Vogel AL, Croyle RT, editors. *Strategies for team science success: handbook of evidence-based principles for cross-disciplinary science and practical lessons learned from health researchers*. Springer International Publishing; 2019. p. 421–44. [https://doi.org/10.1007/978-3-030-20992-6\\_33](https://doi.org/10.1007/978-3-030-20992-6_33).
14. Gillis D, Nelson J, Driscoll B, Hodgins K, Fraser E, Jacobs S. Interdisciplinary and transdisciplinary research and education in Canada: a review and suggested framework. *Collected Essays on Learning and Teaching*. 2017;10:203–22. <https://doi.org/10.22329/celt.v10i0.4745>.
15. Harris S. There are no mistakes on the bandstand [video]. 2011. YouTube. <https://www.youtube.com/watch?v=7shXEFuxHAA> (Accessed Mar 31, 2023).
16. Hoinle B, Roose I, Shekhar H. Creating transdisciplinary teaching spaces. Cooperation of universities and non-university partners to design higher education for regional sustainable transition. *Sustainability*. 2021;13(7):3680. <https://doi.org/10.3390/su13073680>.
17. Holley KA. Doctoral education and the development of an interdisciplinary identity. *Innov Educ Teach Int*. 2015;52(6):642–52. <https://doi.org/10.1080/14703297.2013.847796>.
18. Horcea-Milcu AI, Leventon J, Lang DJ. Making transdisciplinarity happen: phase 0, or before the beginning. *Environ Sci Policy*. 2022;136:187–97.
19. Horn A, Urias E, Zweekhorst MBM. Epistemic stability and epistemic adaptability: interdisciplinary knowledge integration competencies for complex sustainability issues. *Sustain Sci*. 2022;17(5):1959–76. <https://doi.org/10.1007/s11625-022-01113-2>.
20. Jahn T, Bergmann M, Keil F. Transdisciplinarity: between mainstreaming and marginalization. *Ecol Econ*. 2012;79:1–10.
21. Kegan R, Lahey LL. *Immunity to change: how to overcome it and unlock potential in yourself and your organization*. Harvard Business Press; 2009.
22. Kemp SP, Nurius PS. Preparing emerging doctoral scholars for transdisciplinary research: a developmental approach. *J Teach Soc Work*. 2015;35(1–2):131–50. <https://doi.org/10.1080/08841233.2014.980929>.
23. Kligyte G, Buck A, Le Hunte B, Ulis S, McGregor A, Wilson B. Re-imagining transdisciplinary education work through liminality: creative third space in liminal times. *Aust Educ Res*. 2022;49(3):617–34. <https://doi.org/10.1007/s13384-022-00519-2>.
24. Kligyte G, Baumber A, van Bijl-Brouwer M, Dowd C, Hazell N, Le Hunte B, Newton M, Roebuck D, Pratt S. Stepping in and stepping out: enabling creative third spaces through transdisciplinary partnerships. *Int J Students Partners*. 2019;3(1):5–21. <https://doi.org/10.15173/ijasp.v3i1.3735>.
25. Lawrence MG, Williams S, Nanz P, Renn O. Characteristics, potentials, and challenges of transdisciplinary research. *One Earth*. 2022;5(1):44–61.
26. Mathison S. Why triangulate? *Educ Res*. 1988;17(2):13–7. <https://doi.org/10.3102/0013189X017002013>.
27. Nicolescu B. *Manifesto of transdisciplinarity* (Trans. K.-C. Voss). Albany: SUNY Press; 2002.
28. Nicolescu B. In vitro and in vivo knowledge—methodology of transdisciplinarity. In: Nicolescu B, editor. *Transdisciplinarity—theory and practice*. Cresskill: Hampton Press; 2008. p. 1–21.
29. Nurius PS, Kemp SP. Individual-level competencies for team collaboration with cross-disciplinary researchers and stakeholders. In: Hall K, Vogel A, Croyle R, editors. *Strategies for team science success*. Springer; 2019. p. 171–87. [https://doi.org/10.1007/978-3-030-20992-6\\_13](https://doi.org/10.1007/978-3-030-20992-6_13).
30. O’Neill DK. Designs that fly: What the history of aeronautics tells us about the future of design-based research in education. *Int J Res Method Educ*. 2012;35(2):119–40. <https://doi.org/10.1080/1743727X.2012.683573>.
31. Piaget J. The epistemology of interdisciplinary relationships. In: Apostel L, Berger G, Briggs A, editors. *Michaud interdisciplinarity problems of teaching and research in universities*. Paris: Organization for Economic Cooperation and Development; 1972. p. 127–39.
32. Ramachandran A, Abdi K, Giang A, Gladwin D, Ellis N. Transdisciplinary and interdisciplinary programs for collaborative graduate research training. *Educ Rev*. 2022. <https://doi.org/10.1080/00131911.2022.2134312>.
33. Renn O. Transdisciplinarity: synthesis towards a modular approach. *Futures*. 2021;130: 102744. <https://doi.org/10.1016/j.futures.2021.102744>.
34. Saldaña J. *The coding manual for qualitative researchers* (3E [Third edition]). SAGE. 2016.
35. Schnitzler T. The bridge between education for sustainable development and transformative learning: towards new collaborative learning spaces. *J Educ Sustain Dev*. 2019;13(2):242–53. <https://doi.org/10.1177/0973408219873827>.
36. Stein S, Andreotti VDO, Bruce J, Suša R. Towards different conversations about the internationalization of higher education. *Comparative and International Education/Éducation Comparée et Internationale*, 2016;45(1). <https://ir.lib.uwo.ca/cie-eci/vol45/iss1/2>.
37. Stokols D. Training the next generation of transdisciplinary researchers. In: O’Rourke M, Crowley S, Eigenbrode S, Wulfhorst J, editors. *Enhancing communication & collaboration in interdisciplinary research*. SAGE Publications Inc; 2014. p. 56–81. <https://doi.org/10.4135/9781483352947.n4>.
38. Uhlenbrook S, de Jong E. T-shaped competency profile for water professionals of the future. *Hydrol Earth Syst Sci*. 2012;16(10):3475–83.
39. Veisi H, Jackson-Smith D, Arrueta L. Alignment of stakeholder and scientist understandings and expectations in a participatory modeling project. *Environ Sci Policy*. 2022;134:57–66. <https://doi.org/10.1016/j.envsci.2022.04.004>.
40. Vilsmaier U, Lang DJ. Making a difference by marking the difference: constituting in-between spaces for sustainability learning. *Curr Opin Environ Sustain*. 2015;16:51–5. <https://doi.org/10.1016/j.cosust.2015.07.019>.

41. Wickson F, Carew AL, Russell AW. Transdisciplinary research: characteristics, quandaries, and quality. *Futures*. 2006;38(9):1046–59. <https://doi.org/10.1016/j.futures.2006.02.011>.
42. World Economic Forum. The future of jobs report 2023. 2023. Accessed July 25, 2023, <https://www.weforum.org/reports/the-future-of-jobs-report-2023>.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.