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Building Transdisciplinary Research and Curricula: A Model for Developing Cross-Disciplinary Communities Among Faculty in Higher Education

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Abstract: Knowledge and problem-solving approaches that span disciplinary boundaries and involve diverse communities are foundational aspects of transdisciplinarity. Transdisciplinary approaches in research efforts are needed to address complex problems of global importance. At the same time education systems should be preparing graduates to enter the workforce with complex problem-solving skills. Students need to have learning experiences that allow for the acquisition of cross-disciplinary systematic reasoning if they are expected to engage in addressing these complex problems. Recent reports have underscored the need to create university structures and incentives that allow for dynamic and responsive approaches to this global need for transdisciplinary discovery and learning efforts; however, little is known about the efficacy of the approaches and models that have been implemented to create large-scale change in higher education and how they help in achieving transdisciplinary goals. Through an ethnographic case study analysis, this paper examines how a faculty-led community of practice model is being used to build transdisciplinary research capacity and transdisciplinary curricula at a Research I university. Given the unique nature of this transdisciplinary community of practice model, this qualitative and descriptive study sought to examine what elements of the model facilitated faculty participation in transdisciplinary research and curricular efforts. More specifically, this study intended to respond to recent calls to better understand the systematic approach that would need to be employed by higher education institutions if they are adequately engaging faculty in addressing complex problems in their research efforts, as well as engaging faculty in the adequate development of the future workforce through pedagogical transdisciplinary approaches. The findings indicate that the transdisciplinary community of practice model is useful for initially motivating and incentivizing faculty participation. The results also indicate that the inclusive internal support networks that were part of the model facilitated faculty engagement.

Keywords: transdisciplinary; communities of practice; institutional transformation

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1. Introduction

Building capacity to secure external funding and conduct research is an important goal for institutions of higher education. While supporting and facilitating disciplinary-focused research has been and will continue to be one area of focus, universities are increasingly investing in opportunities that require transdisciplinary faculty teams [1]. Due to the

increasing complexity of the scientific problems that impact society, there is an increased need for transdisciplinary approaches that bring together disciplinary [2,3].

Transdisciplinary research is defined as efforts that involve multiple disciplines working collaboratively in the discovery process with the goal of creating newly integrated approaches to address a problem space [4–6]. The research process involves community engagement in the identification of the problem as well as solutions [7]. Definitions surrounding transdisciplinary learning opportunities involve the same collaborative engagement across multiple disciplines and draw heavily on the notion of integrated learning, which suggests that learning experiences intentionally engage students in the process of making connections across concepts and experiences [8–10]. These connections allow students to apply information to new, complex challenges [9–11].

One method for facilitating transdisciplinary research is through team science. There is a wealth of literature on team science that offers insights into how to support faculty who are working in a team-based setting and how to remove barriers in order to facilitate effective teams [12]. The findings from these studies may be of use to faculty teams that receive grants or university administrators who are considering ways to strengthen existing university structures such as centers or institutes. However, the results from these studies offer few insights for universities that do not have teams in place or university leadership and faculty who are considering new paradigms that will allow them to secure external funding. Universities looking to increase research capacity need an understanding of effective mechanisms and models to build teams that go beyond leveraging and enhancing existing traditional structures [8,13–15].

As higher education institutions look to develop graduates with complex thinking skills, the recent literature has highlighted the need for both transdisciplinary educational research [8] and transdisciplinary approaches to facilitate learning opportunities for students [16]. The ultimate goal of combining both research approaches in conjunction with the application of transdisciplinarity is to advance complex thinking skills among students in a manner that allows them to address the most pressing problems facing the world today. The literature identifies approaches such as problem-based learning [17], interdisciplinary majors and minors, and experiential learning opportunities [18] as curricular experiences that can help develop complex thinking skills. To date many of these approaches lack widespread systemic impact. Efforts tend to be course-based, allowing for a singular experience, or involve students self-selecting a specific major that is interdisciplinary in design [8]. As increasing attention is given to the need for complex thinking skills among students entering the workforce, universities need to better understand how faculty are motivated to participate in the creation of experiences that are integrated across the continuum of a student's learning trajectory [8] and connect these experiences with transdisciplinary discovery efforts [18]. Overall, the literature demonstrates that new approaches need to be implemented that can affect widespread change as it relates to creating institutional infrastructure that can advance transdisciplinary research and curricular efforts. However, there is a gap in the literature as it relates to empirical findings about how new models have been effective at achieving goals to advance transdisciplinary efforts. Our study addresses the gap in the literature by examining whether the approach used at one university achieved outcomes related to increasing transdisciplinary engagement among faculty.

This paper discusses an approach used at a Research I university to increase transdisciplinary research and curricular capacity through the creation of faculty-led communities of practice. Our study describes the impetus and emergence of the faculty-led transdisciplinary communities of practice model (TCOPM) and presents a framework to examine the effectiveness of this model as it relates to developing university infrastructure for addressing complex issues that require cross-disciplinary collaboration. This paper identifies the

preliminary lessons learned and presents an overview of whether faculty-led communities of practice can serve as an effective tool for increasing transdisciplinary research and learning capacity.

2. Purpose

Our study looks at one university that implemented the TCOPM as a means to facilitate transdisciplinary research and learning capacity. This study addresses a gap in the literature by examining what elements of the TCOPM advance faculty participation in transdisciplinary research and curricular efforts. The specific research questions included the following:

- What elements in a transdisciplinary community of practice model (TCOPM) advance faculty participation in transdisciplinary research?
- What elements in a transdisciplinary community of practice model (TCOPM) advance faculty participation in the development and implementation of transdisciplinary curricula?

3. Conceptual Framework

Theories surrounding organizational change in higher education suggest that as institutions look to advance new efforts to build transdisciplinary research and learning capacity, models that leverage networks can see positive outcomes [19]. For example, network theories connected to organizational change suggest that relationships can serve as a means to build relationships and facilitate faculty engagement through peer interaction and collective accountability [20–22]. In addition, network theories suggest that social networks can promote information sharing and changes in mindset as social capital is increased. These are additional important considerations as higher education looks to institutionalize new approaches to transdisciplinary discovery and learning efforts [19,21,23].

One way that networks are facilitated is through communities of practice. Communities of practice (COPs) are social networks among which a shared knowledge base develops and there is a core practice or [24,25]. COPs have been used to facilitate change in practice by providing a nexus for social learning [26]. While a COP may focus on social learning among its immediate participants, a COP can lead to more comprehensive changes in practice [26].

COPs have been shown to have wide-ranging positive implications in higher education across a variety of international social and cultural [27]. Facilitating faculty interactions and knowledge sharing has been shown to improve direct classroom instruction in fields ranging from mathematics to health care [28,29]. COPs have also been used to encourage diversity and inclusion outcomes that can impact the student learning experience in universities [30]. The literature highlights how intentional connections that form professional communities between and among faculty can facilitate the adoption of educational innovations [31]. Studies have looked at how research efforts are organized at universities and, while limited, suggest that faculty need to form a strong identity with collaborators from other disciplines prior to engaging in formal research efforts [32].

3.1. Study Adaptation for Community of Practice Framework: Transdisciplinary Community of Practice Model

Given the way that COPs can alter the immediate behavior of participants in the community and have a more far-reaching impact, a COP framework was used to create a model that is intentionally designed to encourage faulty participation in transdisciplinary research and curricular efforts. The transdisciplinary community of practice model (TCOPM) is designed to help define strategic areas of focus for university research and to capitalize

on existing cross-disciplinary strengths. The TCOPM is also designed to serve as an overt means to build transdisciplinary research and curricular capacity beyond traditional structures on campus that included faculty partnerships, academic units, research institutes, and centers.

The TCOPM involves several key elements, including the following:

- Implementation through transdisciplinary communities of practice (TCOPs) that were formed based on thematic areas that spanned a number of complex problem areas and that represented current faculty research as well as the potential to garner significant interest from external funding agencies, corporations, or philanthropies.
- Leadership and direction provided by a faculty stakeholder group for each TCOP that would serve as an immediate community of practice.
- University structural support for the TCOPs, including a program manager that is assigned to work with each TCOP to help with administrative duties, reporting back to the Provost Office on progress, and assisting with the organization and facilitation of the TCOP.
- University funds that the TCOP stakeholder groups spend to support the goals to build transdisciplinary research and curricular capacity.
- Goals for the TCOP that involve creating faculty networks across disciplines, developing curricular approaches that are intended to develop complex thinking skills among undergraduate and graduate students, engaging with community partners by being prominently featured on websites, and securing external funding to support research and curricular efforts in the identified transdisciplinary problem space.

3.2. Institutional Context and the Transdisciplinary Community of Practice Model

The institution selected for this case study was in their third year of implementing an initiative that was intentionally designed to simultaneously build transdisciplinary research and curricular efforts. This initiative was led through the Provost's Office and was designed to increase the visibility of the university in terms of being a place that was at the forefront of solving complex problems. The university anticipated that this increased visibility would attract faculty talent, employers that would seek graduates for respective workforces, and external funding that would further support research and curricular opportunities. The university-wide effort, in conjunction with the three-year timeframe, provided a rich data source for examination.

The TCOPM and related transdisciplinary communities of practice (TCOPs) were established to create faculty interest and engagement in complex problem areas using transdisciplinary approaches. The TCOPs were also established to design and implement a transdisciplinary curriculum that would advance complex problem-solving skills among undergraduate and graduate students. In total, nine TCOPs were launched using the TCOPM, and they are outlined in Table 1. The nine TCOPs were created following a university-level decision making process that looked at nine academic colleges, four research investment institutes, and multiple individual disciplinary areas to identify the areas of strength that cut across traditional disciplinary lines.

The TCOPM and related supporting conceptual framework suggest that in order for a COP to be successful, there needs to be a common value system and clear purpose. The values and clear purpose must identify a set of common goals and milestones that the community agrees upon [26]. To help create a sense of community and common purpose, the TCOPs were charged with developing a white paper to guide their work and asked to outline existing strengths and future potential for research efforts. In addition, COPs often establish boundary objects or tangible representations of the collective thinking [25,33]. In terms of boundary objects, in this TCOPM the TCOPs were charged with creating

undergraduate minors and/or graduate certificates that would represent the complex problem areas they were associated with.

Table 1. The transdisciplinary communities of practice created to facilitate the implementation of the transdisciplinary community of practice model.

Transdisciplinary Community	Thematic Focus
Brain and Behavior	Advancing our understanding of brain plasticity as it pertains to decision making, physical and psychological trauma, and development across the lifespan. Studies enhance the knowledge of the impact of brain–behavior relationships on health and the human condition.
Creativity [Transdisciplinary]	Exploring innovative technologies and the design of creative experiences with best practices for developing impact-driven outcomes and solutions. This TCOP focuses on building and strengthening creative communities, supporting economic development, and enhancing the quality of life via entrepreneurial activities.
Data and Decision Sciences	Advancing the human condition and society with better decisions through data and striving to be a global destination for data analytics and decision sciences, integrating these themes across all areas of the university.
[Transdisciplinary] Materials	Understanding and addressing challenges in scientific materials related to health, energy, the environment, and resilient infrastructure. Efforts span the scope and sequence of material use from discovery and computational modeling to processing, manufacturing, and implementation.
[Transdisciplinary] Security	Focusing on themes related to cyber security, privacy and ethics, governance, and global security. The goal is to understand and foster a world in which people, institutions, and nations are secured by technology and social systems that follow ethical principles.
Engineering and Built Environment	Creating a framework for innovation to enable graduates to reimagine community. This TCOP seeks to address problems that exist at, and along, the interdependencies between humans, communities, and infrastructures to ultimately improve the quality of life.
Social Equity	Engaging with societal problems to advance equity in the human condition, maximizing, wherever possible, the equitable distribution of physical safety and well-being; psychological well-being; and access to crucial material, social, and moral resources.
Global Science	Understanding and finding solutions to critical problems associated with human activity and environmental change that, together, affect disease states, water quality, and food production.
[Transdisciplinary] Policy	Developing novel approaches to policymaking and analysis by focusing on the dynamics of complex decision making in multiple contexts and policy settings. Working at the intersection of scientific evidence, governance, and analyses to translate scholarship to practice.

The COP conceptual framework also notes that there is a need for frequent interaction that facilitates the following: the development of meaningful relationships that allow the purpose of the community to be nurtured and expanded; an opportunity for sustained, deep participation as well as peripheral and intermittent participation that advances the common goals and values of the community; and results that communicate an important, long-lasting effort that can be institutionalized [26]. In alignment with the conceptual framework, TCOPs were charged with generating activities that would highlight the transdisciplinary research strengths in each thematic area and attract attention and external funding to the university to further promote the sustainability of the TCOP. Most of the TCOPs established bi-monthly or monthly meeting schedules. Meeting agendas were primarily concerned

with how to spend funds in order to meet the goals of the TCOP with discussion among the TCOP stakeholder committees. Most TCOPs elected to use their budget to create a call for proposals within the university community to support faculty research tied to their thematic area and awarded funding to faculty teams in seed grants that were less than USD 30,000. The TCOPs also planned and executed speaker series, symposiums, or small conferences that invited external speakers and brought increased attendance from the larger university community and encouraged engagement in future activities and potentially sparked interest from external funding agencies that might provide external investments. The COP conceptual framework also suggested that having a meeting or gathering space for the community was important [25,34]. In this TCOPM the TCOPs often aspired to gain a building or designated connected office space that would allow the community to function as a collective unit. In most cases the TCOPs regularly reserved conference rooms for meetings and seminars.

3.3. Institutional Context and Participants

This study took place at a Research I public university in the United States. At the time of this study, there were approximately 20 faculty members involved in each TCOP stakeholder committee, and they included faculty that are primarily associate and full professor rank. A number of them hold positions as a department head or center/research institute director. Since their inception in 2016, the TCOPs have used the seed funding to provide awards to approximately 40 research teams of faculty members who are not represented in the stakeholder committees. Each TCOP has developed a listserv of interested faculty, and they use that listserv to share information about upcoming events. Events have allowed more than 500 faculty members to engage in different events offered on campus. While engagement with community partners is embedded in the design and implementation of the TCOPM, to date, the TCOPs have not engaged with community partners that can be readily identified.

4. Materials and Methods

In order to understand what elements of the TCOPM provide an effective means to build transdisciplinary research and curricular capacity through faculty engagement, we used a case study methodology. This particular approach was used because of the desire to explore this issue from the participants' perspectives [35]. While the findings from case studies are not widely generalizable, they provide a deep, rich understanding of the phenomenon being studied within a specific context [36]. Three of the TCOPs were selected as a case to examine in detail, through interviews and document analysis, the extent to which the elements of the TCOPM facilitated faculty involvement in transdisciplinary research and curricular efforts.

With regard to the positionality of the research team, both of the researchers were involved in facilitating the implementation of the TCOPM at the university where this study took place. One of the researchers was serving in a university leadership role, while the other was serving as a postdoctoral researcher in the same unit. The design of this study emerged from the daily interactions that the team had with the TCOPM participants, as well as interactions the research team was having with leadership and faculty at other universities who were interested in the TCOPM. In order to encourage the participants to be candid, the postdoctoral researcher conducted the interviews.

4.1. Research Protocol

Because the literature lacks a framework and methodology specific to transdisciplinary communities, especially communities that would span both research and curricular efforts,

the authors leveraged existing and validated frameworks to create the research protocol. As the first step the authors of this article drew on Wenger's [25] community of practice (COP) framework to identify major principles that underlie a COP. Secondly, based on the framework, a series of questions was designed to guide this case study and facilitate a document analysis. The questions guiding this case study and their relationship to the COP framework are outlined in Table 2. The questions in Table 2 are sub-questions connected to the main research questions outlined in the purpose section above. Document analysis was conducted for each of the group's websites, review of events documented and promoted by the TCOP, and meeting notes, and a review of each TCOP budget was conducted. These documents were chosen because they provided insight into how the TCOPs communicated internally as well as with one another. In some cases, the documents also provided examples of boundary objects, or definitive, tangible outcomes produced from the TCOP interactions, that could provide further insight into the manner in which the TCOPs were functioning as a coherent and identifiable group. In total, 39 documents were analyzed.

Table 2. Community of practice principles and questions used in document analysis.

COP Principles	Guiding Questions for Document Analysis
Need a deep commitment to ideas/practices of COP to facilitate innovation and performance; this can allow for mixed paradigm research activities	How did the TCOP express a deep commitment to the principles of transdisciplinarity? Did the TCOP facilitate innovation as it relates to transdisciplinary research?
Need to be nurtured	To what extent has the TCOP been nurtured at the university level? How have stakeholders serving in the TCOP nurtured relationships with one another and with potential participants in terms of TCOP opportunities?
Culture of inclusivity that comes from awareness of power imbalance	How did the TCOP manage power imbalances and create a culture of inclusivity?
Need opportunities for interaction and face-to-face communication	How did the TCOP provide opportunities for interaction?
Should enlist liaisons to work between groups in COP; raise awareness and work between areas	To what extent do the program managers assigned to the TCOPs serve as liaisons? Are there other liaisons that are assisting the TCOP?
Need flexible opportunities for both deep and peripheral participation	What opportunities have the TCOP provided for deep participation? What opportunities have the TCOP provided for peripheral participation? How does the TCOP share knowledge?
Participation can lead to perceived credibility, legitimacy, and saliency of COP	What perceptions of the TCOP are held by the university community?
Creation of boundary objects is important; they provide model or map that allows for interaction [25]	What boundary objects did the TCOP create? How were the objects shared and with whom? Was external funding secured?
Benefit from shared, common space that lacks explicit ownership rules	Are there established common spaces for the TCOP?

Thirdly, once the TCOPs were determined to meet the COP principles in their practice, a series of questions was designed to be used to interview faculty participants to understand what elements advanced or hindered faculty involvement in transdisciplinary research and curricular efforts. Across three TCOPs, 36 interviews were conducted face to face with faculty stakeholders in each community. The stakeholders held the rank of either full professor or associate professor. Individual interviews lasted about an hour and were audio-recorded. The interview protocol asked participants to reflect on their involvement

in the TCOP, their motivation for participation, the goals of the overall TCOP initiative at the university, and the goals of their specific TCOP. Another set of questions asked them to describe the discovery and curricular outcomes of the TCOP and what helped facilitate the achievement of those outcomes and what served as barriers. A final set of questions asked participants to consider the institutional impact of the TCOP and the extent to which they felt the communities would continue to serve a role at the university.

4.2. Interview Analysis

All of the interviews were transcribed verbatim by a professional service, Rev.com. The transcripts from the interviews were first analyzed using an a priori coding process. Two broad categories served as the initial coding scheme, including a) factors internal to the TCOPM and b) factors external to the TCOPM influencing faculty involvement in transdisciplinary research and curricular efforts. Participant experiences were coded within these two areas. The second phase of coding used an inductive approach, and greater delineations in the codes were made as themes emerged. Each member of the research team coded the transcripts on their own and then compared the themes and codes that emerged. Differences in coding schemes were reconciled until the research team had a final set of codes so that rigor in the analysis was [37,38]. A document analysis was used for further contextualization. Each document was analyzed for content in relation to the purpose of this study, focusing on understanding the elements of the TCOPM that advance faculty participation in research and curricular efforts. The analysis used the same guiding questions outlined in Table 2 to provide an initial set of codes for the content being reviewed. Following the initial coding, the second analysis used an inductive approach to allow for the emergence of themes and codes. As the final step in the analysis, the themes and findings were shared with a subset of participants as a means to ensure respondent validation. During the member checking exercise, participants confirmed the themes and findings. In instances where members sought additional clarification about the findings, the research team provided an example of quotations from participants that illustrated the code assigned.

5. Results

Four major themes were revealed in relation to how the TCOPM advances faculty participation in transdisciplinary research and curricular efforts. For each of the four major themes, there are specific elements in the TCOPM that serve to facilitate faculty participation, as well as elements that are missing or serve as barriers to faculty participation in transdisciplinary research and curricular efforts. The four major themes include the following: a need for a common value system; need for a supportive network within the COP as well as externally from university leadership; a need for multiple levels of participation with a clearly understood value statement of how that level of participation benefits the legitimacy of the COP, as well as what the benefits are for the individual participating; and a need for tangible outcomes as well as a defined working space. The four themes and the community elements that aid in facilitation, as well as those that are missing or served as barriers in the TCOPM, are outlined in Table 3 and discussed in the following section.

Table 3. A summary of themes within the community of practice framework: elements and barriers in the transdisciplinary community of practice model.

Themes	COP Principles	Community Elements That Aid in Facilitation	Community Elements That Are Missing/Barriers
Need a common value system	Need deep commitment to ideas and practices of COP to facilitate innovation and performance; this can allow for mixed paradigm research activities	- The TCOP became a home for likeminded people, creating community around a topic area, and group members were able to explain what that topic area means and its importance. - Saw value in a new structure that was different from existing departments, research institutes, and centers. - Actionable follow-up and the achievement of goals were necessary to move beyond a supportive community mentality.	- TCOP participants need a common understanding of the role and purpose of the TCOP committee structure. - TCOP participants need to have a common understanding of university criteria for measuring value. - Some people were asked to be on the stakeholder committees to keep their pulse on things but did not encourage innovative thinking or approaches.
Need a supportive network within the COP as well as externally from university leadership	COP needs to be nurtured	- Relationships were formed by discussing what was meant by each DA. - Relationships were sustained through regular meetings.	- Initial relationships were formed by stakeholders around intellectual curiosity, but is this starting to fade? - Need to move past defining the theme to identifying a complex problem to study.
	Culture of inclusivity that comes from awareness of power imbalance	- A clear expression of the value that different disciplinary approaches provide. - Discussion about challenges or points of contention that yielded conclusive next steps to address differences.	- Disciplinary differences in how or what research is valued can negate inclusive practices if not explicitly addressed.
	COP needs opportunities for interaction and face-to-face communication	- Sponsored events and regular meetings are important.	- It is time for research partnerships to be formulated and built in a genuine manner.

Table 3. *Cont.*

Themes	COP Principles	Community Elements That Aid in Facilitation	Community Elements That Are Missing/Barriers
Need multiple levels of participation with a clearly understood value statement of how that level of participation benefits the legitimacy of the COP, as well as what the benefits are for the individual participating	COP needs flexible opportunities for both deep and peripheral participation	- Stakeholder participation and curriculum leadership are a part of deep participation. - Curricular participation had a clear outcome which encouraged deep participation.	- Deep participation is not widespread due to the time commitment needed and misalignment with promotion and tenure. - Peripheral participation had an unclear value for TCOP stakeholders as well as peripheral participants.
	Participation can lead to perceived credibility, legitimacy, and saliency of COP	- New hires were excited about the idea of TCOPs.	- New and continuing faculty members had challenges in understanding how to participate because the TCOP was not valued in terms of promotion and tenure.
Need tangible outcomes as well as a defined, supportive administrative space	Creation of boundary objects is important; they provide model or map that allows groups to interact	- The curriculum was a form of boundary objects.	- There was a limited number of faculty members participating in curriculum formation and implementation.
	COPs benefit from other places—no man's land/public space with no explicit ownership	- The curriculum needs an administrative home other than a traditional department; this was an important and immediate short-term goal. - Research would also benefit from co-location, but faculty acknowledge that this was hard to conduct and is a long-term goal.	

Theme 1: Need a common value system

One element in the TCOPM that facilitated faculty participation in transdisciplinary research and curricula includes creating a common value system. The value system comprises a likeminded motivation, a well-understood definition of the transdisciplinary problem space and curricular goals, and an action-based agenda tied to the value system.

Participants explained how the TCOPM creates a home for likeminded people whose intellectual curiosity is piqued with the idea of creating new structures that can allow them to more readily address complex problems. Interviewees noted that it was an opportunity to "bring folks that are working in similar fields together to have a home for people that think similarly. . .it's more of a central place that another researcher that's not in that field can go to and say, "Hey, I have some questions." Or, "I need some help. I want to put together a proposal on this. Who would I talk to?""

Faculty participants saw value in a new structure that has the purpose to "create this community around a topic area" and was distinct from existing departments, research institutes, and centers. In addition to providing a community of scholars that were interested

in similar thematic areas, faculty explained that the TCOPM brought faculty members together who were motivated by similar goals such as receiving external funding that could be invested in research around complex problems but allowed them to do so through a new and exciting approach. This sentiment is illustrated by a quote from one TCOP member:

> *Academia and federal funding agencies are extremely stove piped in the sense that just stepping outside of your own department is difficult. And whenever you try to cross this boundary, basically somebody is going to slap you on the wrist and say, "No! You can't do this." I've found it very interesting to actually have an initiative which tries to pretend that these things don't exist. . . .I've found this an attractive starting position, to say, "Okay. Let's take the things we're strong at and let's forget about where they sit in engineering, or the college of science, or in the psychology department, or in Ag sciences. Let's just try to come together, have a conversation, find out what we can make out of this." This I've found, intellectually, very interesting and more engaging than many other administrative interventions where people come and say, "This is the plan. Please sign up to follow it."*

Another participant further illustrated how the TCOPM provided an exciting and innovative approach to pursuing transdisciplinary research and curricular efforts:

> *These intersections are big, gnarly problems that require more than one perspective, and I think we all know to solve some of the big issues in the world today, we need to have that intersection available to us. I think that [university leadership] was visionary in saying you can't assign it to any one domain. You have to have some kind of mechanism where you can come at a problem like autism, or a problem like obesity, or a problem like poverty in an intersectional space. So the [transdisciplinary community model], for me, created those [intersectional spaces] beyond departments and was a mechanism to bring people together who are all interested by the problem, and can bring their skills to bear on that problem. We can't get away from the departments. I think we're not brave enough to do that yet. There are days when I really would like to blow them up. I think they stand in our way.*

Faculty participants explained that an important element in the TCOPM is creating community around a transdisciplinary topic or themed area that group members are able to explain to the university community, as well as external organizations and community members. By first defining and assigning a common importance to the TCOP thematic area, the TCOP participants made critical first steps towards creating a common value system. Having a common definition means that TCOP participants are able to engage a wider group of faculty together across disciplines to address and respond to existing complex problems. One interviewee noted, "there's just so many people with so much expertise across campus, but life being what it is, and the university being what it is, you just don't have a chance to know who's doing what, who you could possibly work with." As part of the TCOPM, having a well-understood mission for the TCOP that resonated with a larger group of faculty meant that participants could easily tap into a group of faculty where there was expertise they needed to tackle complex problems.

TCOP participants noted that an initial discussion about the importance and contributions of the theme area and establishing a clear sense of purpose are critical for implementing the research and curricular goals of the TCOPM. They also explained that it is important to move beyond these discussions and create an action-based agenda. In several cases interviewees noted that the action-based agenda was important because of the need to align with the transdisciplinary goals of federal funding agencies. "You've got to go out [of your own discipline], because even for the funding opportunity from, say, the federal funding or the national funding, they are also trying to encourage transdisciplinary collaborations."

Actionable follow-up and the achievement of goals are necessary to provide continued and new faculty engagement in the TCOPM. Specifically, in the TCOPM, one major way to facilitate faculty participation in transdisciplinary research is to move past defining the theme and its importance and have a defined complex problem or problems to study which can include specific objectives, defined faculty contributions, a timeline, and desired outcomes. The funding that was part of the TCOPM is then allocated to the awardees of seed grants to engage faculty teams in a discussion of how to address these complex problems that fall within the thematic umbrella. One faculty participant explained how it was important to have a clear map of how separate group activities were tied to the larger university goals:

> *The Transdisciplinary Community is formed because each partner feels they can contribute to a certain defined goal. And there's a defined outcome. And during the process, we want to join forces so that we can go out to do grants, we can collaborate in terms of, we co-found teams, to do certain research project.*

A goal-specific, action-based agenda within the TCOPM allowed faculty to move quickly. The TCOPM also provided faculty with the license to make decisions rather than having to seek approval from a director, dean, or higher-level administration.

> *Centers and institutes at the university level, have a whole bunch of policies attached to them, which are entirely at odds with being nimble and doing things quickly. The [Transdisciplinary Communities] meant that we had license to invent stuff as we went, which was very, very useful.*

> *University centers and institutes fundamentally are not well suited for a bottom up approach. I think it's nearly impossible for a group of faculty to congregate and say, "Hey, we want to have a university center." I don't see this, certainly not for an institute. This requires a top down decision, "We're going to have an institute for X." It often requires a donor and so on. . .the [Transdisciplinary Community] in that sense, is more attractive for new things.*

In terms of the elements related to the value system that serve as barriers or are missing from the TCOPM being studied, TCOP participants explained that the TCOPM could be improved if the stakeholder committee structure and purpose of the committees are better understood. One interviewee criticized the lack of action in stakeholder committees and explained that in their experience this was a flaw in the TCOPM design:

> *None of this is happening with the TCOP stakeholder committee [that I'm involved in]. Stakeholder committees seems like a management committee that we're trying to figure out and advise probably either the Provost or the President on how to grow this [TCOPM] administratively. We talk about curriculum, we talk about cluster hiring.*

While the manner in which the committees functioned evolved over time based on continued discussion and the needs of each faculty-led group, the ambiguity regarding original intent and purpose generated a lack of common understanding in some TCOPs about what the stakeholder committees in the TCOPM are supposed to conduct. In some cases, faculty are asked by their college dean to be on the stakeholder committees as a designee to report back to their college on what was happening in the TCOP, particularly as it might relate to the interests of their college. The designee(s) did not take an active role in setting the agenda for the TCOP nor invest time and effort in pursuing the goals identified by the TCOP. Stakeholders that serve as a designee often lack the same values and vested interest as other self-motivated stakeholders. Another element of the TCOPM that prohibited engagement is a lack of a clear understanding of the university's criteria for measuring

the value the individual TCOP contributed to the university's transdisciplinary research and curriculum goals. One TCOP participant illustrated this with the following quote:

> *the unclear future direction. . .we are doing all this work, but what if, say, half a year later or a year later, all the efforts we are putting in are not worth it anymore, because like I said, these people, we have deans, we have department heads, they are all really busy people, but they are all really willing to put in all the efforts and time to discuss how to move the TCOP forward. . .but hearing lack of clarity on the future direction, really putting some kind of doubt in your thoughts to say, "How much effort do I need to put in? I think that's the challenge.*

Theme 2: Need for an inclusive internal and external support network

The results also highlight that the TCOPM facilitates faculty participation in transdisciplinary research and curricula by creating an inclusive supportive network within each TCOP that facilitates regular interaction and recognizes the importance of organic relationships. Having an external support network in the larger university community that values and supports the TCOPM also impacts faculty participation.

In terms of internal support networks, an important element in the TCOPM that facilitates faculty participation in transdisciplinary efforts includes an inclusive climate that allows divergent views to be reconciled in a way that values different disciplinary strengths and provides a clear contribution for many different disciplinary efforts. TCOP participants noted that in order to facilitate transdisciplinary research and curricula, a culture of inclusivity was needed to shape TCOP actions and engagement. The TCOP needs a clear expression of the value that different disciplinary approaches provide. Participants also explained that a discussion about challenges or points of contention that yielded conclusive next steps to address differences was important for an inclusive culture. If discussion was ongoing or repetitive without yielding a common understanding and ability to move to action, faculty disengaged.

The TCOPM also facilitates faculty involvement in transdisciplinary research and curricula through regular meetings that stakeholders use to discuss how to spend the university-provided budget and plan campus events. Regular meetings also involved discussion about what research proposals should be funded and whether they aligned with the transdisciplinary research goals of the TCOP. The findings suggest that the TCOPM, with an emphasis on research and curricular goals, facilitated faculty involvement because regular interactions involved the discussion of multiple topics. Faculty participation was encouraged because both research and curriculum development were discussed, such as undergraduate minors that could be offered university-wide to undergraduates.

Another important part of the TCOPM internal support networks that facilitates participation in transdisciplinary research and curricula consists of efforts that recognize that research partnerships take time to form and need to be genuine rather than accidental or staged. One interviewee explained, "I think we should focus on "collaborative dialogue . . .. whether it leads to collaborative research or not, I can't predict that but I don't want to push that because research has to happen organically. Two people have to sit down together over a glass of wine, a cup of coffee and say that maybe we should do something together on that problem."

In terms of the barriers and elements lacking in the TCOPM being studied, TCOP participants identified external support networks in the larger university community as it relates to organizational considerations, clear metrics for success, financial commitments, and department systems for promotion and tenure as major barriers to faculty involvement. One participant explained how a lack of external support networks in the TCOPM at the

university level in terms of organizational considerations impedes faculty involvement in transdisciplinary curricular efforts:

> *People put more emphasis on how we split the money, how we split the tuition. . .everyone is more concerned about protecting their territories. Do we have any better mechanisms to actually get people together towards a common goal, instead of protecting their territories? That's something that concerns me. Each time, the curriculum comes up, I see people saying "This should be coming from my department or [these courses] should be coming from your department. If you're trying to get my students across the border to take courses in your department, then I will be losing my tuition to you." This type of thing just does not foster the environment to be collaborative.*

Others made similar points about the struggles of using limited college resources to develop transdisciplinary curricula by pointing out how much extra time and energy such efforts would require. As one senior faculty put it, "If you're really going to transform the curriculum, getting new kinds of classes approved and actually executed, then [faculty] need extra graduate students to help us with this stuff and we just don't have it."

In terms of an external support network, the findings suggest that if the elements of the TCOPM do not include a consistent budget and clear metrics for success, faculty involvement in transdisciplinary research and curricular efforts will be inhibited. One participant noted, "I feel like all of the ambiguity . . .people have lost interest." Another participant explained, "I think that that lack of firm support from the top, leads to sort of a shakiness financially. Even though ideologically I'm on board, financially it's on shaky ground and its future is on shaky ground." This interviewee went on to argue that "[as a member of this TCOP stakeholder committee] I didn't know whether or not all this work that I put in would even come to fruition." Another faculty TCOP member provided additional context:

> *I think the only thing that I would say as feedback kind of to the administration is that they have to be very careful about wasting faculty time, because the one way to kill support, and you need the support of the faculty in these kinds of initiatives, is to have them work hard, and then find out you didn't really know what you were going to do, so all that effort was for naught. I've seen a lot of people pull away from the TCOP, so if you want to try to bring them together again and get them excited about something, it's going to be tough because they've got a very sour taste in their mouth right now.*

Participants also questioned whether metrics for research success are aligned with the length of time that research relationships take to be built and yield results, especially in emergent transdisciplinary field and problem areas. Due to the lack of consistent university funding, the TCOPM was continuously challenged in terms of facilitating widespread faculty participation.

In terms of barriers in the TCOPM at the departmental level, promotion and tenure practices were identified as an element preventing faculty involvement. Without this type of support, participation was viewed as a risk-taking behavior that is misaligned with the criteria used to evaluate promotion and tenure. One faculty member explained the following:

> *I'm not sure that faculty are convinced that putting time and effort into a Transdisciplinary Community is equal to, or more valuable than putting time and effort into their research, their teaching, what the department requires. And I haven't felt, from the point of view of the Transdisciplinary Community that we have more of a claim on faculty than again, their department or their other affiliations.*

Theme 3: Multiple levels of participation that are valued: deep versus peripheral

Our findings indicate that in order to facilitate faculty participation in transdisciplinary research and curricula through the TCOPM, there needs to be multiple levels of participation that involve, as defined by Wenger (1998), deep commitments as well as peripheral opportunities to engage as time allows. Regardless of the level of participation, in order to facilitate faculty involvement in transdisciplinary research and curricular efforts, it needs to be clearly understood how the level of participation benefits the TCOP's efforts, as well as the individual faculty member.

In the model studied, deep participation comes from the stakeholders of the TCOP that meet regularly. Regular meetings included monthly one- to two-hour face-to-face meetings involving the entire group of stakeholders. This core group primarily includes faculty members who were associate and full professors and research institute directors. Deep participation is actualized by establishing the call for proposals for seed grant funding, making budget decisions, and participating in the design and implementation of the curriculum, including the internal governance process and related administrative work. Deep participation is motivated by affordances such as full professor status and well-established research agendas. Participants explained that deep participation was facilitated because it was already valued by the faculty members engaged. Heavily engaged TCOP participants also noted that deep participation in the curriculum was driven by a compelling inherent desire to create curricular experiences for students that addressed the thematic area.

An element of the TCOPM that prevented faculty engagement in transdisciplinary research and curricular effort was a lack of understanding of how this engagement would benefit them personally:

> *Faculty are very myopic, let's be frank here, okay? I think most people are interested in their research and only in their research. If they're going to do something else they want to see a direct benefit. So the good citizens will care about the public good and they will think about what's the direct benefit to the department. But most people will take it one step further and say, well if the direct benefit is to the department and there's no direct benefit to me, why should I bother? People are rational, faculty are definitely smart, intelligent, rational people.*

Deep participation with the development of new cross-disciplinary curricula is also a challenge because faculty need to gain department head approval to teach outside of their department and engage in the development of curricular offerings that would attract students from a variety of majors. As a result, department-focused teaching needs tend to take priority, presenting a challenge for faculty outside of the department to teach courses with their peers from other colleges, and this is especially challenging for newly hired faculty. Deep participation in research efforts was better supported because of the opportunity for scholarly activities that were aligned with promotion and tenure criteria:

In terms of advising new hires, the following is often said to them: "Here are your priorities in terms of being a successful faculty member, and earning promotion and tenure. What do you need to do?" There are some for whom an association with a TCOP can be very positive. It can build collaborations. It can advance their research, it can help them with publications, and it can create opportunities to apply for grants.

In the TCOPM being studied here, peripheral participation was an element that advanced faculty participation in transdisciplinary research and curricula if there was a clearly articulated objective for the peripheral participants to continue to engage with the TCOPs. In most cases peripheral participation involves the awardees of the seed grant funds that were distributed by the TCOPs. The majority of seed grant awardees were not stakeholders, and they submitted proposals because their research was aligned with the thematic area. Once seed funds were awarded, the awardees often did not engage with the stakeholders, and most did not have any motivation or explicit requirement per the

award guidelines to engage with the stakeholder committee. However, in instances where the TCOP asked awardees to present their findings from the research to other seed fund awardees and members of the TCOP, they felt that there was a clear reason their research teams should continue to build relationships with others beyond the TCOP stakeholders. Yet, this rarely ever happened, and when it did it was often limited to discreet activity, often mediated by a member of the TCOP stakeholder committee.

Peripheral participation also involves faculty who taught pre-existing courses that had been integrated into the newly created TCOP minors that the stakeholder committees were charged with developing and implementing. Peripheral participation also involves participation from the larger university community in seminars or conferences. Faculty acknowledged that the impact on the community or how the community's work was shared and built upon as a result of the participation in seminars and speaker events was challenging to measure.

Theme 4: Need tangible outcomes as well as a defined, supportive administrative space

The final theme that emerged from our study, as we looked to understand the elements in the TCOPM that facilitate faculty involvement in transdisciplinary research and curricula, is the need for tangible outcomes and a defined and supportive administrative space. Most interviewees underscored the importance of establishing their curriculum and formal approval of their minor by institutional governance as a major milestone and creation of a boundary object.

> *At a personal level, I have to say, what I enjoyed about the TCOP, I met a lot of people on campus, very bright and motivated people, which I otherwise never would have met. This for me, probably is the biggest personal benefit from that. In terms of curriculum, I think, we have created this minor. And getting a minor through and all that is a major amount of stuff which needs to get done. I think without the TCOP structure this would not have happened. That's clearly a success.*

Interviewees also noted that the transdisciplinary research goals that are part of the TCOPM would also benefit from being co-located near or in the same vicinity as one another because this would encourage further cross-TCOP collaborations, information sharing, etc. However, faculty readily noted that the co-location of TCOPs on campus would be hard to achieve, and they recognized that it would take several years to create an innovative space that was designed to facilitate interaction.

6. Discussion

This paper explored what elements of a transdisciplinary community of practice model (TCOPM) used at a Research I university encouraged or hindered faculty involvement in the engagement of transdisciplinary research and curricular efforts. The findings suggest that the model can serve as a way to increase transdisciplinary capacity through faculty engagement if certain elements of the model are included. This study also yielded important results about how the absence of certain elements in the model can hinder faculty participation. Other institutions of higher education can use these findings to consider how to develop and implement TCOPM policies and infrastructure to address complex issues that require cross-disciplinary collaboration.

The findings indicate that the TCOPM can enhance traditional organizational structures within universities that are designed to facilitate the achievement of transdisciplinary research and curricular goals. In the context of this study, the implementation of the TCOPM with explicit goals surrounding the development of transdisciplinary research and curricula, as well as engagement with external groups, was an innovative and exciting idea that initially drew faculty to become involved. The initial launch of the model coupled with

messaging from university leadership allowed faculty who were interested in the thematic topics identified to find an immediate group of collaborators.

Implementing the TCOPM, with the development of thematically based TCOPs, can serve to bring faculty from across the university together in a thematic space, facilitate networking, broaden the research scope and interests of junior- and senior-level faculty, and lead to new and innovative transdisciplinary curricular approaches. The results demonstrate that in order for the model to successfully engage faculty in these activities, there needs to be sufficient time for the TCOP to develop a common value system and purpose. In the TCOPM studied here, the university identified thematic groups based on existing strengths and launched faculty stakeholder groups that would serve as a community of practice from the outset. Despite having pockets of pre-existing faculty expertise in certain areas, most of these faculty members had never worked together before joining the stakeholder committee. In order to facilitate faculty engagement, the stakeholders needed time to form an initial community that included identifying a common value system. Faculty noted that valuing the investment of that time through university reward structures was an important factor for involvement. Moreover, in the TCOPM studied here, TCOPs that moved from developing a common value system and purpose to an action-based agenda that had clearly defined research projects and curricular goals were more likely to engage faculty consistently and over a longer duration.

The findings also reveal that as part of the TCOPM, the TCOPS need to develop inclusive support networks that allow for the reconciliation of disciplinary differences in order to facilitate faculty involvement in research and curricular efforts. These networks also need to be nurtured through regular meetings and engagement efforts. Furthermore, the findings demonstrate that the TCOPs would benefit from a broad scope of initiatives that need to be discussed, including tightly coupled research and curricular efforts, so that many different faculty interests are encouraged.

The findings indicate that while faculty leadership is important, the TCOPM would be more likely to achieve outcomes with regard to building transdisciplinary research and curricular efforts if the model is nurtured by external networks at the university level through sustained base funding and if the model has clearly identified expectations for metrics identified from the outset.

The literature underscores that the creation of boundary objects is important for the credibility and institutionalization of communities of practice. Boundary objects and the achievement of milestones provide a model or map that allows groups to interact. This study also revealed that in the context of the TCOPM, these boundary objects, in this case establishing formal curricular efforts, need to be supported by external networks at the university including university and department leadership so they align with the faculty reward structure and receive long-term university investment.

The results demonstrate that consistent with the COP literature, there needs to be opportunities for deep and peripheral participation to build a legitimate TCOP that is a key element of the TCOPM. An important finding is that regardless of the level of participation, faculty must be aware of how participation and the investment of time benefit the community, as well as what individual benefits they will receive. If faculty are not aware of how their investment of time will benefit the TCOP, they are likely to refrain from continued participation. Likewise, if faculty are unclear on how participation in the TCOP is relevant to promotion and tenure, they are unlikely to engage, especially untenured faculty.

Finally, the findings suggest that the TCOPM would further facilitate faculty engagement in transdisciplinary research and curricular efforts if, in addition to thematic space, TCOPs were provided with defined physical space. The results reveal that TCOP fac-

ulty need a place to meet, conduct their work together, and invite other faculty into that defined space.

This study provided important and timely considerations for institutions of higher education that are looking to build their transdisciplinary learning and research capacity. Professional organizations and the related literature have emphasized the need to consider team science-based approaches to solve the complex problems facing society. However, empirical findings are lacking that consider models for the implementation of systematic change that are based on team science concepts. This study identifies the aspects of the TCOPM that need to be present in order for a university to effectively launch and sustain faculty engagement in transdisciplinary research and learning efforts.

While the findings yield important considerations for universities looking to develop their transdisciplinary research and learning capacity, this study is not without limitations. This study was conducted at one university. It may be the case that the nature of the current organizational structure, in terms of the number and type of disciplinary programs, where this case study took place influenced the faculty responses. Future research could replicate this study at other institutions that use a community of practice model to facilitate transdisciplinary learning and research. While this study focused on factors encouraging faculty involvement, future studies could examine what factors incentivize university leadership involvement and the implementation of new paradigms for organizational infrastructure.

7. Conclusions

In conclusion, this study presented the elements of the TCOPM for consideration as universities look to develop their transdisciplinary research and learning capacities. The findings from this study demonstrate that the TCOPM can provide a unique and innovative approach to encouraging faculty involvement in research and discovery surrounding complex problems. The TCOPM created new faculty networks and resulted in collaborative, innovative approaches with multidisciplinary teams of faculty that would not have had an opportunity to connect otherwise. The TCOPM also resulted in the development of curricular approaches that would allow students to gain complex thinking skills with faculty from across the university collaborating on the design and learning outcomes. New minors and courses were developed as a result, and the design was restructured to allow for exposure to transdisciplinary ideas. Additionally, the TCOPM allowed for more immediate transfer from research activity to the classroom and curricular opportunities with institutional scale. Other institutions can learn from this study with regard to the organizational support and funding that need to be coupled with the TCOPM to further advance faculty engagement in transdisciplinary approaches in higher education.

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