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Toward Transdisciplinarity: Constructing Meaning Where Disciplines Intersect, Combine, and Shift

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Abstract

Although literacy research has traditionally focused on content area and disciplinary literacies; in this study, we argue for the importance of transdisciplinarity. We employed a participatory action research design to examine pre-service teachers' (PST) planning of a transdisciplinary math and music lesson to understand how conceptual framing of pedagogy and instructional practice can be shifted from content literacies to transdisciplinarity. Our area of inquiry focused on how PSTs' understanding of transdisciplinarity shifted as they planned, taught, and reflected on instruction and how these shifts were supported by others. We documented evidence of how the lesson progressed from disciplinary thinking to interdisciplinary, multidisciplinary, and transdisciplinary thinking throughout the planning process. We also documented how the process of planning, teaching, coaching, and reflecting provided PSTs with an opportunity to better understand the connections between transdisciplinarity and pedagogy.

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Introduction

Many important societal problems are neither simple nor easily solved; they are wicked problems (Zellner & Campbell, 2015). A wicked problem is a social or cultural challenge that involves many social systems and groups, has unpredictable outcomes, and defies typical problem-solving techniques (Rittel & Webber, 1973). To address a real-world, wicked problem like climate change, a transdisciplinary lens is needed to support educators and students as they engage with this content in ways that extend beyond traditional academic boundaries (Alford & Head, 2017). Transdisciplinarity is a research or educational approach that seeks to challenge disciplinary boundaries to create a holistic perspective that provides opportunities to connect across scientific and nonscientific communities (Mauser et al., 2013). A transdisciplinary lens allows one to construct meaning in more authentic contexts where disciplines intersect, combine, and work together (Rice, 2013).

The challenge is that as literacy education moves from a focus on content area reading and writing to disciplinary-specific practices (Fang & Coatoam, 2013), this draws the field away from the power that can be gained by a transdisciplinary focus. As the research field moves further into the subject and discipline-specific practices, we create more silos in and out of our classrooms as we prepare teachers and educate students (Hartwell et al., 2017). A transdisciplinary focus pushes back against silos of content areas as it considers these varied intersections of content and allows educators the opportunities to seek pedagogy and assessment practices that are authentic and allow for transcending traditional paradigms of disciplinary spaces (Yeung et al., 2021). Educators and researchers are left with the fundamental question of whether we need to erase the boundaries between disciplines or do we need to—in a sense—harden them so that students stay committed to the content area literacies. A transdisciplinary lens, through its ability to address complexities in the world, is consistent with moving beyond a strong disciplinary literacy focus.

Before the emergence of transdisciplinarity, interdisciplinarity has been a regular theme in education (Williams et al., 2016) as evidenced, for instance, by the recent popularity of Science, Technology, Engineering, and Math (STEM) and Science, Technology, Engineering, Art, and Math (STEAM) education. The movement toward interdisciplinarity and integrated pedagogy is happening for a variety of reasons, from making lessons more in line with the complex nature of the future of work to creating activities that are more engaging, authentic, and equitable (Casillas et al., 2019). The challenge is that while integrating, combining, or juxtaposing different disciplines the combinations may exist on a solely superficial level (Gouvea et al., 2013). Interdisciplinarity allows one to observe, analyze, and evaluate different ways of relating different fields, whereas transdisciplinarity describes a blurring of the separation between disciplines and construction of meaning in a more real-world context

where disciplines intersect, combine, and work together (Williams et al., 2016). The imperative is then to consider how teachers, including pre-service teachers (PSTs), can gain a deeper understanding of integrative movements in education to create more meaningful learning opportunities for students.

In this study, we employed a participatory action research design (Kemmis et al., 2013) to examine PSTs' planning of a transdisciplinary math and music lesson from the early stages of planning to teach. The research question we sought to answer was how can conceptual framing and instructional practice be shifted from content literacies to transdisciplinarity? Our area of inquiry focused on how PSTs' conceptual framing of transdisciplinarity shifted as they planned, taught, and reflected on instruction and how these shifts were supported by others. We documented how PSTs made sense of transdisciplinarity as they developed the lesson.

Theoretical Perspectives

As literacy, learning, and pedagogy change in a digital age, it is important to adapt and react as future evolutions warrant (McLaren & Jandric, 2014). The change is also consistent with the push toward transdisciplinarity as "disciplinary boundaries are artificially imposed and often create barriers that cause fragmentation in understanding" (Jao & Radakovic, 2017, p. 183). As Takeuchi et al. (2020) remind us, the views on transdisciplinarity depend on the ideologies and worldviews we chose to employ. In the context of this study, we have a strong commitment to content knowledge and the importance of existing curricula, whereas other ways of dealing with transdisciplinarity start from more holistic approaches based on individual student experiences (Osborne, 2015). Educating and empowering youth to be active, engaged, positive, and globally connected citizens require that we reposition education as a creative and diverse endeavor where epistemological differences are valued (Burnard et al., 2022). We used a multiple theoretical perspective approach (Labbo & Reinking, 1999) that connects perspectives from content area literacies, disciplinary literacies, meta-disciplinarity, and transdisciplinarity in education.

Content Area Literacies

Content area literacy can be defined as the ability to use reading and writing for the acquisition of new content in a given discipline. It is the ability to identify, understand, interpret, create, communicate, and compute using printed and written materials associated with varying contexts (Marsh, 2019). It includes the cognitive and social practices involving the abilities required to be literate in an area as students read, comprehend, critique, and write about multiple forms of print (Hull & Moje, 2012). These forms of text include multiple formats including textbooks, novels, magazines, online materials, and other signs and symbols that convey information, emotional content, or ideas (Serafini, 2011).

Disciplinary Literacy

Disciplinary literacy is the ability to read, write, speak, listen, and think in a given content area (Hillman, 2014; Hinton & Suh, 2019). It is often used interchangeably with *content area literacy*, but they are quite different. Content area literacy suggests that educators across the content areas should work together to support students' general reading comprehension strategies (Lent & Voigt, 2018), whereas disciplinary literacy considers the ways experts within a discipline uniquely read, write, think, reason, and process information (Dobbs et al., 2020). The challenge is that supporting students as they read, write, speak, listen, view, and think like experts in and across disciplines can be a complex pedagogical exercise (Collins et al., 1988).

Interdisciplinarity

Some theories of education shift the focus from understanding formal concepts to meaning-making to encourage students and educators to cross-disciplinary connections (Dunkerly-Bean & Bean, 2016). As instruction moves away from traditional understandings of content areas and disciplines to craft new blended content areas (e.g., Humanities, STEM, STEAM), there is an opportunity to find content area literacies in the context of other disciplines as different practices, skills, content, and dispositions work together synergistically to understand the object of inquiry (Brozo et al., 2013). This includes a desire on the part of the educator to study "individual attributes, at the nexus of institutional and material practices and textual cultures, instrumentality, and the production of agency and identity" (Basu et al., 2008, p. 769). Educators seek not for disciplinary purity and isolation, but to employ multiple disciplines and their content, practices, skills, and dispositions around mutual areas or objects of inquiry (Smith et al., 2018). Instruction may also focus on teaching strategies that integrate multiple domains of knowledge into a single unit of studies, such as authentic learning (Herrington et al., 2014) or project-based learning (Kokotsaki et al., 2016).

Transdisciplinarity

As we have detailed, research and practice in educational contexts can be framed as a continuum starting from content area silos and a disciplinary focus to more of an integrated interdisciplinary connection that includes multidisciplinary associations. The concept of transdisciplinarity is slippery, in flux, and has a plurality of definitions (Klein, 2013). One of the features of transdisciplinarity is blurring and transcending disciplines (Russell et al., 2008). These spaces have been shown to provide fertile grounds for exploring patterns of change, transformations, and invariants in and across content areas.

There are many perspectives on transdisciplinarity (Burnard et al., 2022; Klein, 2013); however, as education researchers interested in incorporating transdisciplinarity

into our classroom practices, we gravitate toward the definitions that specifically incorporate how transdisciplinarity views disciplines (i.e., school subjects) and their role in society. Thus, we consider the following features of transdisciplinarity:

(1) Traversing: crossing disciplinary boundaries (Wiseman & Lunney-Borden, 2018)
(2) Transcending: moving beyond disciplinary paradigms (Pohl, 2010)
(3) Transforming: focus on the socially relevant issues and the common good (Klein, 2013; Pohl, 2010).

In addition, as we traverse, transcend, and transform, our actions can be seen as an act of resistance. This creates the need for the fourth element:

(4) Transgressing: an openness to resist, interrogate, and transform established boundaries and disciplinary structures. This necessarily involves including new voices which can be seen as an act of resistance (Hooks, 1994).

Framing transdisciplinarity around these four elements gives us a way to operationalize it and identify it in our practice and data analysis.

Methodology

This study employed a participatory action research design (Kemmis et al., 2013) to examine PSTs' planning of a transdisciplinary lesson from the early stages of planning to teach. Participatory action research is appropriate in this context because we worked collaboratively with PSTs to make sense of transdisciplinarity embedded in instruction to understand the connections researchers made with the area of inquiry and their role in the field of education (Reason & Bradbury, 2008). We investigated how PSTs plan for a transdisciplinary lesson in the context of composing music using online music software. Our area of focus explored how PSTs, just beginning their study of teaching and learning, made sense of transdisciplinarity. We were interested in the words used to explain transdisciplinarity, breakthroughs the students made in their understanding, and finally, the lesson they created to operationalize transdisciplinarity in the classroom. We frame our research around the following question:

> How can the conceptual framing and instructional practice of pre-service teachers (PSTs) shift from content literacies to transdisciplinarity?

Context and Participants

This research was conducted at a small liberal arts university in the southeastern portion of the United States. The researchers are four professors who teach in a department of teacher education housed in this institution of higher education. Nenad Radakovic is an associate professor focusing on mathematics education in the

context of K-12 and PST education. W. Ian O'Byrne is an associate professor of literacy education who focuses on the literacy practices of individuals in online hybrid spaces. Melissa Negreiros is an assistant professor whose research focuses on the use of instructional technologies to advance a focus on social good. Tracey Hunter-Doniger is an associate professor of creativity and creative arts in education. This research was assisted by two PSTs who were students enrolled in programs in the department of teacher education. At the time of this research, Emily Pears was a student in the Masters of Education in a theater arts program, with a background in musical theater, and Cymone Littlejohn was a sophomore, early childhood education major with an extensive background in music and music theory. All of these perspectives and backgrounds are necessary as we made connections between and across our different disciplinary vantage points.

The lesson developed by the PSTs was implemented in the university-based summer camp (Camp Art Attack) and organized by the fourth author. This camp was a segment of Creativity and Creative Arts in Education, a course designed to teach preservice generalists how to integrate the arts. The camp met for four consecutive days, for four hours each day, and lasted two weeks. The curriculum was STEAM-based and completely designed by the PSTs. STEAM is an integrative pedagogical approach that brings together Science, Technology, Engineering, Arts, and Mathematics using transdisciplinary, interdisciplinary, multidisciplinary, cross-disciplinary, and/or arts integration (Perignat & Katz-Buonincontro, 2019).

Data Sources

Data consisted of audio and video recordings of the coaching sessions with the PSTs. Data also included field notes taken from the teaching of the lessons, PST reflections after each phase, and all teaching materials. This included different drafts of a lesson plan. In addition to the detailed reflections after each phase, all authors completed the short reflection form after the coaching sessions and lessons. For a detailed description of the data sources used, see Table 1. It is important to note that the focus of data sources was on PSTs and their reflection rather than on children's thinking about transdisciplinarity. When children's work was discussed, it was in the context of PSTs meaning-making.

Data Analysis

For the qualitative data analysis, the Grounded Theory approach was used (Creswell, 2002) by using types of coding, namely open coding, axial coding, and selective coding (Strauss, 1987). The data analysis was done in three stages as outlined below.

Stage 1. Open coding was involved in the initial stage of the analysis of the transcribed data. In this stage, Emily and Cymone individually went through each other's reflections and coded for emergent themes. Then they agreed on the

Table 1. Sources of Data anrd Responsible Parties.

Audio and video recordings of the coaching sessions	• Group meetings were video recorded for use in analysis and to triangulate with other data sources. • Included discussions where PSTs and researchers developed or critiqued instructional plans and materials. • Captures of PSTs as they practiced teaching lessons, taught the lessons, and reflected with researchers.
Planning and instructional materials	• All drafts of the lesson plans were collected as well as other teaching materials such as PowerPoint slides, handouts, etc.
PST Journal and Lesson Reflections	• Emily and Cymone's reflections on the progress of lesson planning, coaching sessions, their understanding of transdisciplinarity as well as the reflection rubric.

Researcher field notes	• Researcher observational notes were collected during the study.
	  • Observations of individual and group discussions in class
	  • Instructor support in class and online
	• Additional notes on specific strategies used, modifications made, or problems encountered during the study.

following codes and created a coding manual (see Table 2). Examples of these codes included: Struggle to define transdisciplinarity/purpose of lesson and transdisciplinarity, facilitating discovery, technology, and instruction and planning. Emily and Cymone then presented the codes to Nenad and Tracey for review, at which point, Emily and Cymone coded all materials.

Stage 2. After this round of open coding, axial coding was used to look at the connections between the existing themes organized in the first round of coding (Strauss, 1987). For example, the team looked at the connection between disciplinarity and transdisciplinarity, planning and transdisciplinarity, and coaching for transdisciplinarity. As detailed below, all members of the research team used focused dialogue to coach each other as they developed understandings of transdisciplinarity, using math and music as initial reference points.

Stage 3. Using selective coding (Strauss, 1987), the team looked at instances that illustrated the themes, created narratives based on the themes, and answered the research question. Specifically, we used the results from stage 2, to create a narrative of how PSTs collaborated among themselves and with the professors to achieve transdisciplinarity and how PSTs, as well as the professors' view of transdisciplinarity, evolved throughout the research process. For the purposes of triangulation, the group looked at the videos of rehearsal of the lessons using the same codes. To

Table 2. Codes Generated After the First Cycle of Open Coding.

Code	Qualifiers for Code
T—Transdisciplinarity	Struggle to define transdisciplinarity/purpose of lesson and transdisciplinarity
I—Instruction/ inexperience	Problems with instruction/inexperience—productive struggle
C—Coaching	• Scaffolding • Checking for understanding • Open-ended questions • Prep and support • Leveraging differences
D—Discovery	Facilitating discovery, not giving too much away, hiding the math
Tech—Technology	• Teaching technology • The issues with the technology • How this technology represents numbers
K—Background Knowledge	Background knowledge having an effect on both teachers and students.
F—Freedom	Freedom or autonomy during the lesson
Col—Collaboration	Collaboration of teachers and students • Group Dynamics • Energy in the Room
Feel—Feelings	Feelings throughout the process of teachers and students • Focus • Nervous • Fear • Frustration

serve the same purpose, Ian, who did not participate in coaching, observed the lessons to create his reflection. He also examined the codes to ensure accuracy. He then used the agreed-upon codes to examine the reflections. Triangulation of these data sources (Kern, 2018) allowed for a greater understanding of the opportunities and challenges that existed as we integrated technology and transdisciplinarity into math and music.

Findings and Discussion

This study investigated the process of lesson making and how conventional conceptual framing and instructional practice can shift from content-centric literacies to transdisciplinarity. As part of this inquiry, we investigated how the PSTs progressed in their understandings of pedagogy and literacy from content area literacy and disciplinarity to transdisciplinarity. As we worked with the student researchers, we were presented with an opportunity to explain transdisciplinarity to our students and reflect as we grappled with these spaces. To capture the complex interactions and multiple layers involved in pedagogy that addresses wicked problems, we needed to transcend

solely disciplinary conceptual framings of pedagogy. In this study, we trouble the established disciplinary connections and synthesize epistemological and methodological approaches to focus on knowledge synthesis and construction in student inquiry. Throughout the study's progress, the PSTs shifted to a better understanding of the blending or transforming of disciplines and fields, and, ultimately, created and taught a transdisciplinary lesson to children.

We had two major findings in this study. First, this process of planning, teaching, coaching, and reflecting provided PSTs with an opportunity to better understand the connections between transdisciplinarity and pedagogy. Second, we outline the concept of meta-disciplinarity that came out of the data analysis and we see it as a step that connects interdisciplinarity with transdisciplinarity.

Educators Expanded the Conceptual Framing of Pedagogy as They Plan, Teach, and Reflect

The purpose of this study was to investigate the process of lesson making and how conventional conceptual framing and instructional practice can shift from content literacies to transdisciplinarity. Throughout the study's progress, the PSTs shifted to a better understanding of the blending of disciplines and fields, and, ultimately, created and taught a transdisciplinary lesson to the children in the camp. As such, the development and teaching of the lesson were very important as they helped further the goals of our inquiry. The PSTs were tasked with creating a lesson that would teach a math and music lesson while also embracing transdisciplinarity and technology. Our varied areas of expertise helped focus our research as we considered the development of a lesson that connected music and mathematics. The words used, breakthroughs achieved, and coaching of PSTs will be fully described below.

Teaching a Transdisciplinary Lesson. With guidance from the researchers, the PSTs decided they wanted to incorporate the concept of arithmetic sequence as represented by equally spaced notes on Online Sequencer (https://onlinesequencer.net/), a free digital music online program that uses synthesized instruments. Online Sequencer was selected for use because it was user-friendly and would allow participants with varying degrees of musical comprehension to be successful. The interface of the Online Sequencer displays a visual pattern of notes to help users sketch out a song and see where notes of different instruments will sound at the same time. The lesson developed by the PSTs, under the coaching of the researchers, illustrated their conception of transdisciplinarity embedded in the classroom. During the lesson, the students were to use Online Sequencer to create a composition consisting of four different sequences of notes that follow an arithmetic sequence. The students were shown a simpler task consisting of two sequences.

The lesson began by introducing the PSTs to the students and indicating the purpose of this lesson. After this introduction, students and the PSTs clapped out beats and

audibly counted them as they clapped. Some students clapped out beats in patterns of twos, some in threes, and others clapped every four beats. They quickly realized that there were times they all clapped at the same time. After the quick demonstration of patterns and number sequencing, the PSTs introduced the Online Sequencer to the learners and provided a brief overview on how to operate the program and create a musical composition using a single percussion instrument. The students were given time to play with the program and create their musical compositions.

The PSTs then modeled how to add a second and third instrument to the interface of the Online Sequencer. They then assisted the children as they listened, and then added new instruments to the digital sequence. The students were then allowed to freely explore the application and see what kind of music they could create until they felt comfortable with the program. Students were then given the task to create a pattern in the program that would use a minimum of four sequences and include a certain number of beats per measure in the sequence (e.g., two beats, four beats, six beats, and seven beats). It was hypothesized that this task would be an opportunity to organically identify content and learning that exists in between and across these disciplines. Once that was completed, the PSTs and students reviewed the sequencer and could visualize how the notes aligned and were able to leverage technology to make the connection between mathematics and music.

Drawing Connections Between Pedagogy and Transdisciplinarity. The PSTs and researchers' insistence on framing the study outside of disciplines of mathematics and music, gave children the opportunity to explore the composition in different ways and to move freely between subject areas. This also enabled them to create their own discourse systems rather than stick with disciplinary terminology. For example, Cymone reports on children's use of the note that appears at every 7th beat as not aligning with other notes (at 2nd, 4th, and 6th beats) as "stubborn":

> They liked the higher notes and they stated that if they had more time they would have changed the low notes. They saw the low note as a grumpy stubborn old man. They assigned the 7 as stubborn because it was always off-beat with the other numbers. The other numbers were even and seven was odd. There was already a bad connotation of seven when they started. (researcher field notes, 6/14/2018)

In other words, students created their authentic terminology to describe the fact that the least common multiple of 7 and 2, 4, and 6 was a high number (i.e., the smallest number that the sequences of multiples of 7, 2, 4, and 6 share is 84). Since 7 was odd and relatively prime to other numbers (e.g. they had no factors other than 1 in common), children described this property as "stubbornness." The idea of "stubbornness" allowed students (as well as PSTs) to explore the connection between relative primeness and common multiples which is a fairly advanced topic in number theory. We see this as evidence of transdisciplinarity because we allowed students to freely "traverse" between different disciplines without any disciplinary

commitments. This enabled them to create a language that transcended both music and math in terms of their definitions as disciplines. We suggest that what happened here was a blending of disciplines as learners created a new space of math and music. Patterns are not clearly defined as either notes or numbers or markings on the software; rather the children are left on their own to decide how to define the elements. Problem-solving skills and dispositions are also not strictly bound to disciplines. Rather, a skill of perseverance ("not giving up") and the ability to manipulate software as well as communicate with your partners become important.

Reflecting on Transdisciplinarity. A couple of weeks after the lesson was taught, we had a post-instructional conference about the use of transdisciplinarity. In this process, we employed the Davis and Renert (2014) idea of collective sense-making and the application of complexity in education. We looked deeper into the way that we might have used transdisciplinarity and why this matters. At first, we focused on formal definitions of transdisciplinarity. Our conceptual framing then moved to think about transdisciplinarity etymologically and metaphorically. Gradually, our discussions progressed to consider and explore metaphors, more specifically the concept of *silos* to understand transdisciplinarity.

Silos. Silos on a farm are designed to store various types of grain in separate 30-foot cylinder-shaped storage units. Essentially, the design of a silo is to keep the grain isolated. In traditional schools, the curriculum maintains a silo-like design, keeping the subjects and disciplines isolated and artificially separated (Goldman & Pellegrino, 2015; Leshner, 2018). Disciplines are taught during designated time slots, with discipline-specific textbooks, where students listen to content-exclusive lectures and complete activities based on that same subject (Fonger et al., 2018). This model is based on ideas from the Industrial Revolution and is considered the most efficient way to educate children (Carl, 2009; Vande Zande, 2010). It is an artificial approach to learning filled with imposed constraints (Ingersoll et al., 2018). The education system is fragmented by silos and children are not taught how the pieces fit together or how they need to fit together to effectively support each other and to create the most useful whole (OECD, 2018). Transdisciplinarity breaks down the silos and provides an enriched experience that is more true to life in that disciplines are experienced simultaneously rather than in isolation (Vaughan et al., 2019).

An example of this is shown in this conversation which expanded on the notion of transdisciplinarity:

Ian:	Silos, in each silo are math and music. What we are doing with transdisciplinary lessons is breaking down the silos.
Emily:	I see it more [fluid, like a] water tank with music and math in each compartment.
Emily:	(second thought): [I see] each liquid a different color and removing the compartment then seeing the liquids mix together.
Ian:	Oh confluency, like where two rivers meet, mixing together and blending all the sediment and water.

Tracey: I see it like mixing paint, originally new colors being formed, but they maintain the original color but work together with the others, creating more of a pattern.
Ian: Kind of like a marbled pattern or a monoprint?
Tracey: YES! (researcher field notes, 6/28/2018)

As described above, each discipline has characteristics that can be blended with others. The river metaphor converges all the components of two completely separate rivers combining the elements to form a new mixture. The particles from each river branch are there, but it is difficult, if not impossible, to point out the separate elements. This does not sufficiently describe transdisciplinarity. The marbling metaphor provides an accurate account of a transdisciplinary lesson. The colors are blended, they are beautiful together as they swirl around creating intricate, detailed patterns. The important factor is that the colors hold their integrity. They do not blend or change, they work collaboratively with the other colors creating a unique design that is never the same. Burnard et al. (2022) expand this idea by indicating that this creativity of pedagogy is "not democratized when opposing agendas in education dictate the implementation of fixed, dis-embodied, fractured practices" (p. 168).

Educators Shifted from Discipline-Specific Conceptual Framing to Transdisciplinarity

As we documented the shift from disciplinary thinking to transdisciplinarity, another step emerged from the data which involved understanding the structure of disciplines and identifying connections between them. We identified this concept as meta-disciplinarity.

In the existing literature, meta-disciplinarity is the understanding of the structure of a discipline, "of what the discipline is, what it tries to accomplish, and how it tries to accomplish its aims" (Wright, 2019, p. 366). Meta-disciplinarity is important in the framing of this study as it goes beyond one discipline into the structural understanding of various disciplines to make comparisons and connections between disciplines (Sukhodimtseva et al., 2018). This linkage provides the methodology and discourse structures necessary to work with more than one discipline to consider a central topic, event, or fact (Jenlink, 2015). Meta-disciplinarity includes practices such as generalizing ideas, drawing parallels, developing classifications, choosing proper classification grounds and criteria, finding out causal relationships, building logical reasoning, and making conclusions (inductive, deductive, analogical) (Sukhodimtseva et al., 2018).

Disciplinarity. The PSTs were given a brief introduction to transdisciplinarity. However, as the PSTs started planning the lesson, the focus shifted away from the explicit study of transdisciplinarity. As Emily stated in her reflection, "I hadn't

really been thinking about transdisciplinarity at all. I knew that we had created a task that used both music and math at the same time, and I was just focused on making our idea work." Through working on the task, the researchers were aware of the disciplinary differences in their approaches. In other words, PSTs started with disciplinary thinking while keeping in mind the transdisciplinary goal. To make sense of this, PSTs needed to break apart the content areas to rebuild them using a transdisciplinary lens. In the interviews, Emily stated that she focused more on math since this was not her "strong subject," whereas Cymone felt that she focused more on music because of her background in music. In Emily's words, "we have all been approaching this differently because of our different background knowledge—we all bring something different to the table—a different perspective."

Interdisciplinarity. PSTs initially understood the objective of making a composition as a musical task that contains mathematical elements (e.g., finding the least common multiple). This corresponds to the model of interdisciplinarity in which two disciplines are intact but used to understand the object of inquiry (making a composition). Consistent with theoretical framings of interdisciplinarity, each subject (math and music) has its own way of looking at compositions. In our work, these two ways were "synergistically" used to look at the composition.

Meta-disciplinarity. Meta-disciplinarity involves a deep structural understanding of the problem from each discipline (patterns of numbers vs. patterns of notes) and how the two relate. As stated earlier, Emily and Cymone started with disciplinary perspectives but then realized for them that the purpose of the activity is to make meaningful connections. Emily reflected on this in a journal entry:

> Hoping that this would lead to some meaningful music connections--because that's what we want too, we don't just want them to make math connections--it's about using both disciplines and making meaningful connections in both at the same time and maybe that makes all the learning more meaningful and worthwhile because the students constructed it on their own by doing a task that hopefully facilitated those connections (researcher field notes, 6/22/2018).

These "meaningful connections" show evidence of meta-disciplinary thinking as the PSTs understood the structure of disciplines and then started to make connections between them (e.g., connection between the concept of patterns between two disciplines).

Transdisciplinarity. To approach transdisciplinarity, PSTs created a lesson in which students were instructed to make a composition without the implicit mention of mathematics. The students were presented with the problem of using multiple sequences of notes and finding where the notes would terminate. The result was the use of the blend of mathematics and music as students were free to use patterns of notes or

numbers and problem solve in any way they chose. They were also free to move between disciplines (traversing).

The task of creating a composition moved from being focused on mathematics and common multiples and shifted to a more open focus to allow for connections in other content areas, perhaps even beyond math and music. For example, instead of presenting the lesson simply as a problem of alignment of different sounds, Nenad suggested that one of the questions should be, "What can make your composition even better?" He also wanted to make sure that the students had an opportunity to name their compositions. This opening of the lesson moved away from mathematics and presented opportunities for connections in other disciplines.

Conclusion

This work seeks to better understand opportunities to shift the conceptual framing and instructional practice of PSTs as they seek to embed transdisciplinary literacies in the classroom. On a more basic level, this study seeks to understand transdisciplinarity by seeking a common theoretical space for a group of educators and developing a shared discourse to engage in this inquiry. Transdisciplinarity is a concept with many meanings (Klein, 2013) and the opportunity to explore its meaning is critical for PSTs and teacher educators as they seek to transcend the disciplines (Ojamaa et al., 2019). The core concept is an understanding that no one content area or discipline can provide the appropriate knowledge, practices, and dispositions needed to address the complexity of a wicked problem (Mishra & Koehler, 2007). Although situated within the context of math and music, this study contributes to addressing the complexity of wicked problems because it shows how two disciplines work together to understand a phenomenon.

We believe that the pedagogical model we presented here could be used in the future to explore the pedagogy of wicked problems. The challenge of developing pedagogical opportunities to address real-world, wicked problems like climate change may be limited by the conceptual framings we bring to these endeavors. To better comprehend the possibilities to transcend or transgress human systems and ecologies, we believe there is a need to understand and develop transdisciplinary educational and research approaches and models. In this study, we examined how PSTs grappled with transdisciplinarity as they wade into the tumultuous waters between math and music. We described one way to approach transdisciplinary learning: through a deep structural understanding of disciplines, interdisciplinarity, meta-disciplinarity, and transdisciplinarity.

A transdisciplinarity lens challenges educators and researchers to consider the spaces in which learning occurs and overcome established paradigms and competition within and between disciplines (Vaughan et al., 2019). This research provides opportunities to expose the hidden internal assumptions and contradictions in literacy education and research by inviting us to take advantage of the etymological and linguistic exploration of the concept (King, 2007). The human conceptual system is inherently metaphoric (Lakoff & Johnson, 1980) and provides us with a powerful

analytic philosophy to approach transdisciplinarity and the words used to define it (i.e., traversing, transcending). We seek not to find the "true" meaning of the word and associated constructs but to expand or shift understanding by offering different orientations, directions, and flexibilities.

Framing the study as participatory action research was integral in creating metaphors of transdisciplinarity as the research team worked together to understand our area of inquiry. Our conceptual understanding of transdisciplinarity was informed by the literacies, practices, and discourses we each brought to the endeavor. One of the crucial elements in this study was an environment of trust and respect that was established early in the process. Throughout the study, there was an understanding that it is appropriate and valuable to make mistakes and that errors are not a failure, but an entry point to learning something new that created an atmosphere of constant reflection and reiteration (Richert, 1990). This nonthreatening learning environment provided within the coaching process accelerated the learning curve for teaching a transdisciplinary lesson of math and music (Gardiner, 2012). A certain amount of flexibility and ambiguity is necessary as instructors and learners work together to design spaces for creativity and divergent thinking (O'Byrne et al., 2018).

This study demonstrated the work that goes into these explorations and the importance of collaboration between teacher educators and PSTs to make sense of transdisciplinarity. We hope that our work will motivate other researchers to conduct research with learners in different contexts as they contend with transdisciplinarity. Specifically, our introduction of meta-disciplinarity as a step between interdisciplinarity and transdisciplinarity provides an opportunity for researchers to explore these spaces and the tension between disciplinary and transdisciplinary literacies. Our findings reveal the need to provoke the field to consider the possibilities, challenges, and affordances of transdisciplinarity in current and future educational contexts.

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