

MATHEMATICS EDUCATION RESEARCHERS' PRACTICES IN INTERDISCIPLINARY COLLABORATIONS: EMBRACING WAYS OF KNOWING

Elizabeth Suazo-Flores
Purdue University
esuazo@purdue.edu

William S. Walker, III
Purdue University
wswalker@purdue.edu

Hanan Alyami
Purdue University
alyamih@purdue.edu

Signe E. Kastberg
Purdue University
skastber@purdue.edu

Mahtob Aqazade
Rice University
mahtob.aqazade@rice.edu

Mathematics education researchers (MERs) engage in interdisciplinary collaborations that contribute to the mathematics education discipline. MERs' learned forms of work and discourse, i.e., practices, are particular to their mathematics education discipline and might not align with practices needed to conduct interdisciplinary work. We interviewed four MERs who were leaders of interdisciplinary groups to learn about practices they reported using while collaborating with their groups. Using qualitative content analysis, we describe five practices commonly reported by the four MERs. We argue that these five practices are central ways of knowing and doing for MERs when working in interdisciplinary groups. Our study contributes to the mathematics education discipline by unpacking practices MERs use to engage in interdisciplinary groups that are influenced by interpersonal relationships.

Keywords: Mathematics education, interdisciplinary collaborations, practices, disciplines.

Mathematics Education Discipline and Work

Disciplines are defined by Williams et al. (2016) as a "phenomenon" involving "specialization" of work and discourse (p. 4). Disciplines are constantly evolving while increasing their specialization and differentiation. For instance, mathematics education as a discipline has evolved from being informed by the disciplines of psychology and mathematics (Kilpatrick, 2014; Stinson & Walshaw, 2017) to embracing disciplines such as neuroscience (e.g., Norton et al., 2019), science education (e.g., de Freitas & Palmer, 2016), and anthropology (González et al., 2001; Gutiérrez, 2013). Disciplinary practitioners are introduced to disciplinary ways of knowing and doing in their training programs. Mathematics Education Researchers (MERs) develop their professional identity by learning research practices within the discipline of mathematics education. In their career, practitioners gain status in their discipline by engaging in disciplinary forms of discourse. MERs further interact with practitioners from other disciplines and collaborate in interdisciplinary groups.

MERs have engaged in interdisciplinary work to address complex problems. For instance, Civil joined González from anthropology to explore funds of knowledge (González et al., 2001). Norton joined colleagues from computer science to develop software systems (Jones et al., 2015) and neuroscience to explore students' anxiety (Norton et al., 2019). Davis joined colleagues from various disciplines to explore spatial reasoning (Bruce et al., 2017). We can learn about MERs' interdisciplinary collaborations from publications, but because the collaborations are not the focus of the publications, descriptions about the process of interdisciplinary work are thin. Schön (1992) stated that practitioners of a discipline do their work by using more than "research-based technique" (p. 54). Conducting work involves aspects such as interpersonal relationships where people act and work towards solving important problems and finding common ground (Fletcher,

1998). Interpersonal relationships involve social exchanges that welcome and lift people involved academically and emotionally. We argue that working in interdisciplinary groups is more than contributing discipline specific expertise, it involves the negotiation of disciplinarity through interpersonal relationships. This includes paying attention to ways of being, interacting and doing within the groups. It also includes identifying disciplinary-based practices that are essential, can be modified or compromised, or do not align with the interdisciplinary work.

Because members of interdisciplinary groups have been trained in their respective disciplinary ways of knowing, communication and representation differences might emerge when coming together. Bruce et al. (2017) reported that members of an interdisciplinary group need to study "discipline-specific vocabularies and methodologies" and articulate problems so that all members can "identify and situate themselves" (p. 158). Goos and Bennison (2018) described the value of disciplinary knowledge to interdisciplinary team members. In addition, team members felt threatened when their disciplinary knowledge and ways of operating were not recognized professionally when "working outside their discipline" (p. 267).

Disciplinary ways of knowing and doing work are called practices (Hyland, 2004; Williams et al., 2016). In this paper, practices and practice categories are italicized to help the reader recognize when words or phrases are being used to describe practices. Building from existing research (e.g., Cobb & Yackel, 1996; MacIntyre, 1984; Schön, 1983, Wenger, 1998), Suazo-Flores et al. (2021a, para. 4) defined practices as "established ways of *being*, *operating*, and *interacting* with others." Suazo-Flores et al. (2021a, para. 9) found that in interdisciplinary groups, MERs engage in practices such as *working towards research interests*, *cultivating trust and open-mindedness*, and *understanding of institutional support*. Building from this work, we interviewed MERs who worked in interdisciplinary groups. Our initial analysis resulted in a revision of the categories of our definition of practices, where:

Being [...] refers to MERs describing their view of themselves and others in the interdisciplinary group including specific roles taken on by group members. *Operating* [...] means members' ways of doing in the interdisciplinary group and acknowledging institutional policies and actions in order to complete the work. *Interacting* is [...] developing communication standards, negotiating the meaning of ideas that allows the group to collaborate, and explaining work to people outside of the group. (Suazo-Flores et al., 2021b, p. 827, italics added)

With this revised definition, we conducted further research to address the question: What practices did MERs commonly report using in interdisciplinary research groups?

Methods and Analysis

This research is part of a larger project focused on describing MERs' lived experiences of working in interdisciplinary groups (Suazo-Flores, et al., 2021b; Suazo-Flores, et al., 2021c). Four MERs from three different projects who identified themselves as members of interdisciplinary research groups volunteered to participate in this research: Amelia, Ian and Alexis, and Iris (pseudonyms). Amelia was a faculty member as well as a primary developer and leader of her interdisciplinary project. Her project involved improving curriculum and pedagogy for university pre-service mathematics education programs. Ian and Alexis collaborated on a project to create engineering tasks that would allow students to learn new mathematics content. Ian was a graduate student and Alexis was a faculty member and Ian's advisor. Iris was a faculty member and leader of a project between mathematicians and mathematics teacher educators. The project developed curricular modules to help students learn mathematics content. We conducted

three semi-structured interviews (Kvale, 1996) with the four MERs (Ian and Alexis were interviewed together) focused on practices that developed and were used in the interdisciplinary groups. MERs shared the story of the interdisciplinary group, ways of doing in the group, and reflections as a member of the group. For example, we asked MERs to describe situations when working in the group was an asset or a constraint.

To create codes and definitions for the categories of practices and to identify examples, we used grounded theory (Charmaz, 2005) to code Amelia's transcript (Suazo-Flores, et al., 2021b). Each practice was categorized as *being*, *operating*, or *interacting* and assigned a short descriptive phrase. Three phases of analysis resulted in a codebook with definitions of the practice categories, descriptions, and examples of different practices. For example, the following excerpt was coded as the practice *acknowledging a personal view of self* within the *being* category.

Amelia: For me, it's been a wonderful growing experience. So, I don't feel like I've lost anything because I still have my life in my discipline, and I have a much enriched and expanded life as well by having these experiences that I didn't realize I was going to get.

Amelia referred to her *personal view of self* as an MER noting, "I still have my life in my discipline." She also recognized that her work in the interdisciplinary group had "enriched and expanded" her life. We identified this as a way of *being* because it provided evidence of her evolving identity as an MER through her work with people from other disciplines.

We then used the codebook to code all three interviews. Evidence of practices reported by the four participants in the form of interview transcripts constitutes our data. A deductive approach using the codebook allowed for analysis of the transcript data consistent with qualitative content analysis, such that the coding and analysis included two steps: "the first is a qualitative-interpretative step following a hermeneutical logic in assigning categories to text passages; the second is a quantitative analysis of frequencies of those assignments" (Mayring, 2015, p. 366).

For reliability, each transcript was coded by a member of the research team using the codebook and then checked by a second member of the research team. When coding differences between researchers were found, the coded practices were discussed by the entire research team to share reasoning and clarify codes. Once agreement was reached regarding the use of a code or its definition, the codebook was updated. Once this qualitative-interpretive step was completed, the codebook was updated and the coded items in each of the transcripts were reviewed for alignment with the updated codebook (c.f., Mayring, 2015).

Following the final coding of the three transcripts, frequency tables were created to identify how often each practice occurred in the data. Table 1 is the frequency table for the five practices described in this paper. The frequencies of the coded practices were disaggregated by project and show the amount of evidence from each of the projects used to make a claim. For example, there were 22 instances where the *being* practice *acknowledging a personal view of others' roles* was coded across three interview transcripts. Disaggregation showed that 6 of these codes were from Amelia's transcript, 9 of these codes were from Ian and Alexis' transcript, and 7 of these codes were from Iris's transcript. The frequency tables allowed for the identification of practices that were common between all of the participants. This research presents the five practices that were reported in each of the three transcripts at least three times.

Table 1: Frequency Table for Common Practices

Category	Practice	Amelia	Ian and Alexis	Iris	Total
Being	Acknowledging a personal view of self	4	6	20	30
Being	Acknowledging a personal view of others	6	9	7	22
Interacting	Developing ideas between partners	6	7	3	16
Operating	Working towards common goals	9	5	5	19
Operating	Using ways of working together	4	3	4	10

Findings

Our analysis identified five practices MERs commonly reported using in their interdisciplinary groups: *acknowledging a personal view of self*, *acknowledging a personal view of others*, *developing ideas between partners*, *working towards common goals*, and *using ways of working together*. The first two practices are in the *being* category, the third practice is in the *interacting* category, and the last two practices are in the *operating* category. Below, we describe each practice and use examples from the data to illustrate the category.

Being: Acknowledging a Personal View of Self

Acknowledging a personal view of self was coded as a type of *being* practice. This practice involved MERs using individual identity, including their dispositions, interests, sense of efficacy, and roles to engage with others in the group's work. Our participants showed evidence of recognizing their roles and dispositions in their interdisciplinary groups. For example, Ian indicated, he "was the central person" who at the beginning of the project "was trying to meet the needs of so many people," which we interpreted as him acknowledging his role in the group and others' expertise. In Iris' research group, she described how she was "not a mathematician," but brought her vast teacher education background to the project, "I have lots of experience in working with teachers."

Being: Acknowledging a Personal View of Others

Acknowledging a personal view of others was classified as a *being* practice because participants described how they perceived others as part of the interdisciplinary group. The code *acknowledging a personal view of others* was used when participants described other group members as members of a discipline, as taking on special roles in the group, or as influential members due to the added diversity of knowledge/experience. For instance, Iris described a member of her interdisciplinary group as having a "very strong mathematics background" with experience in the "high tech industry" and "a high school teacher." Iris acknowledged the member's expertise and experiences and appreciated that both were committed to "narrowing the gap between school mathematics and contemporary mathematics," which was the main goal of the interdisciplinary project. As a member of Ian's interdisciplinary group, Alexis described how she recognized roles and expertise in her colleagues. Alexis stated, "the primary role that the team members play was to bring their expertise to the table," and she noted that "Ian really was

the lead in designing the material or coming up with the context and coming up with the activities."

Interacting: Developing Ideas Between Partners

Developing ideas between partners was coded as an *interacting* practice because MERs reported how group members negotiated the meaning of ideas, representations, or frameworks. When MERs described developing understandings and common definitions that allowed members of the group to collaborate and communicate to external audiences, we coded those instances as *developing ideas between partners*. For example, Iris indicated that she and a group member who was a mathematician had "arguments on the buildup, on the things that [the mathematician] thought would be very accessible." Iris and the mathematician had discussions regarding unpacking the mathematics content and making it accessible to students. She explained that such discussions allowed them to develop new ways to represent mathematics to external audiences. "I don't think I would be able to do it on my own, and I don't think he [the mathematician] would be able to do it on his own." In another example, Amelia indicated how it was important for the interdisciplinary group members to develop ways of communicating. Amelia described that given the different disciplinary expertise, people in the group needed "to be good listeners and very respectful and making it possible for questions to be asked and to be able to respond to those questions in a way that's serious and takes things seriously."

Operating: Working towards Common Goals

Working towards common goals was classified as an *operating* practice because the use of common goals was a factor in "ways of doing" for the groups. This practice was described by the participants when they shared purposes or common goals used by the group to focus the work being done. There were also times when MERs described working with the interdisciplinary group to develop common goals. Such instances were classified as an *interacting* practice like *developing ideas between partners* (see above) because developing goals involved exchanging ideas to build shared understandings. *Working towards common goals* was coded when (1) the group goals were described by a participant, (2) it was clear that the goals were established, and (3) it was clear that the goals were used to focus the work being done. For instance, Amelia's articulation of the initial purpose of her interdisciplinary group is that "it was a funded project" and that "the central purpose kept [them] together. So those two goals were always there." Ian described how the group's purpose was to create a curriculum for the "learning of new mathematics and new engineering at the same time."

Operating: Using Ways of Working Together

Similar to *working towards common goals*, *using ways of working together* is classified as an *operating* practice because it represents "ways of doing" for a group. *Using ways of working together* is how an interdisciplinary group worked as a team or a process that the group used to get work done. Iris described her work as "a true teamwork." She encouraged the mathematician to "set up a storyboard, so to speak," to tell the story around the targeted mathematics concept. Later, they worked together to add the "know-how" pieces. This is how the new story around the targeted mathematics concept began "with a question instead of starting with declarations." In Amelia's research group, she described how different group members already had different systems in place. The group shared these other systems, which created a menu of items, "and then we each picked something from that menu that we decided to try this approach next year, and then we swapped and learned from each other." The group developed a way of working together to learn from each other by picking different approaches from the menu.

Discussion

We have described five practices MERs commonly reported using in their interdisciplinary groups. Two practices are in the *being* category, one in the *interacting* category, and two in the *operating* category, respectively: *acknowledging a personal view of self*, *acknowledging a personal view of others*, *developing ideas between partners*, *working towards common goals*, and *using ways of working together*.

The practices identified in this research provide evidence that conducting interdisciplinary work is more than contributing disciplinary expertise, as asserted by Schön (1992). MERs used the *being*, *interacting*, and *operating* practices to navigate interpersonal relationships and conduct interdisciplinary work. The *being* types of practices reflect how MERs saw themselves in relation to others and how they perceived others in their groups. The practices of *acknowledging a personal view of self* and *others* allowed MERs to acknowledge disciplinary expertise and navigate work with others by finding common ground and contributing to the interdisciplinary group work. The *interacting* practice, *developing ideas between partners*, identifies the development and use of discourse norms within interdisciplinary groups to understand, listen to each other's perspectives, and build common understandings. The *operating* practices of *working towards common goals* and *using ways of working together* describe "ways of doing" in interdisciplinary groups. Members of interdisciplinary groups worked towards goals that met their interests and the interdisciplinary project; they also developed work systems that built from each other's expertise and backgrounds.

Because the members of interdisciplinary research projects come from different disciplines, that have different practices (Williams et al., 2016), MERs need to use *interacting* practices, which allow the group to negotiate and develop a common language among themselves and for external audiences. MERs in our study had discussions of meanings within the groups to conduct the interdisciplinary work and communicate the product of the collaboration to external audiences. For instance, Ian described how he acknowledged different peoples' expertise and then realized that his role and other team members' roles allowed the project to be more successful. Iris described the integral role of diversity in her team, highlighting the need to discuss ideas with colleagues from different disciplinary backgrounds to construct new knowledge. Amelia's description of team members' approach to interactions as "good listeners and very respectful" aligns with descriptions of dispositions of team members provided by Bruce et al. (2017). We also noted that the common language the members of the interdisciplinary group developed was unique to the members of the group and the project's final product. For instance, Iris reflected that it took many discussions for the group to narrow down ways of representing the product of their work to others. Iris' interaction with her colleagues and the consideration of how external audiences would use the project was instrumental in developing a way of communicating the work. Iris recognized that this important goal could not have been realized without each team member's contributions and expertise.

Once the group members have used *interacting* practices to cultivate a common language and framework, *operating* practices develop. We identified two operating practices: *working towards common goals* and *using ways of working together*. For instance, Iris and her group used the story system to start with the pure mathematics content to add know-how prompts that would allow the audience to have entry points to engage. Amelia and her group built from each of their experiences in teacher education to learn from each other instead of using mandating systems.

Our study exemplifies Williams et al.'s (2016) definition of disciplines for mathematics education. Mathematics education as a discipline has evolving forms of discourse and work. As

MERs are being asked to join interdisciplinary groups to expand the boundaries of mathematics education research (Cai et al., 2020), we advocate for professional development spaces where MERs reflect on ways of *being*, *interacting*, and *operating* in such groups. MERs need to learn how to productively work outside of their discipline and, with that, expand their expertise. MERs need to consider their role in the project and their personal goals in relationship to the project's goals and the group members from other disciplines. MERs also need to create spaces where members of interdisciplinary groups can openly discuss ideas. In such discussions, MERs need to acknowledge their colleagues' expertise and recognize that as a group in dialogue, new ideas will emerge that inform the final product of the interdisciplinary work.

The results of this research are influenced by the fact that each of our participants were leaders of their interdisciplinary groups. MERs as members of interdisciplinary groups led by others may contain practices not captured here. Similarly, more studies are needed to explore how power relationships influence work in interdisciplinary groups that include a MER. The study reported here did not capture the breadth of experiences that members of the research team have experienced as MERs on interdisciplinary projects, suggesting that additional work is needed. Similarly, studies on how MERs' race and ethnicity backgrounds influence their interpersonal relationships and practices in interdisciplinary groups are also needed.

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