Faculty Perceptions of Making Connections: A Story of Obligations and Constraints

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Mathematics is central to STEM coursework, yet limited research has examined how instructors in math and other STEM courses facilitate connections between courses for their students. Based on four focus group meetings with ten faculty members, we characterize factors that assist or hinder making connections between courses and examine their relationship to professional obligations. Results include the largely negative impact of institutional obligations on faculty's willingness and ability to make connections. Implications include the need for institutions to give opportunities to make personal connections across departments and incentivize the development of connections.

Keywords: interdisciplinary connections, professional obligations, instructor decision-making

Introduction and Background Literature

Faculty in science, technology, engineering, and mathematics (STEM) disciplines recognize that math is relevant to their students and their teaching, as evidenced by requirements for students to take specific math classes for their major and the related role of math as gatekeeper to STEM (e.g., Bressoud et al., 2015). Nevertheless, while examinations of better ways to connect math and science or engineering have occurred at administrative or departmental levels (e.g., Robayo et al., 2022; Vroom et al., 2022), limited work has directly attended to individual faculty members' experiences. We thus seek to address the following research question: What factors assist or hinder connections that faculty can make between courses/content areas?

Meaningfully connecting content between disciplines is challenging, as jargon forms barriers to non-members of those communities of practice (Wenger, 1999). Separations exist between STEM faculty members and, by extension, their courses. Thus, research has begun examining how content like definite integrals and bases are communicated and used in different disciplines and how differences impact students' understanding (e.g., Jones, 2015; Serbin & Wawro, 2022).

Furthermore, STEM educators have placed increasing emphasis on math skills or concepts undergirding scientific content and ways instruction can better relate these content areas. Foci include interpretations of graphs in math and science (e.g., Christensen & Thompson, 2012; Rodriguez et al., 2018; 2019) and connections between content in particular courses, such as calculus and biology or chemistry (e.g., Jones, 2019a; 2019b; Williams et al., 2021), calculus or differential equations and physics (e.g., Jones, 2015; Roundy et al., 2015; Schermerhorn & Thompson, 2019a; 2019b; Smith et al., 2013), and linear algebra and physics (e.g., Schermerhorn et al., 2022; Serbin et al., 2020; Wawro et al., 2020). Some work also seeks to connect higher level math to science, including relating discrete math or abstract algebra to chemistry (e.g., Bergman & French, 2019; Bergman, 2020) and biology (Robeva et al., 2010). Considering the many interfaces of math and science, it is understandable that STEM majors may struggle to draw on appropriate math coursework in their science and engineering courses and that math faculty may be unaware of how their content is used in other courses. This paper builds on these cross-disciplinary efforts by examining how the use of focus groups centered on connections between courses' content could be used to illuminate current connections made between courses and gain insight into faculty's perspectives on what could support making connections in future.

Theoretical Perspective

To conceptualize factors that impact making connections between content areas, we draw on professional obligations as characterized by Herbst and Chazan (2011). This perspective is grounded in the theory of practical rationality, wherein mathematics teachers' instructional actions are taken to be sensible based on the norms and obligations that motivate them and theorizes what norms and obligations are impactful to teachers' decision making in different contexts. Whereas norms characterize the typical roles a teacher would play in instruction, professional obligations are characterized as "justifications (or refutations) that participants might give to actions that depart from a situational (or contractual) norm" (p.450). They also characterized four categories of professional obligations: disciplinary, individual, interpersonal, and institutional. Disciplinary obligations relate to providing a valid representation of mathematics as an area of knowledge and a practice. Individual obligations include the need to attend to students' identities and needs. Interpersonal obligations relate to shaping interactions and classroom discourse. Institutional obligations relate to attending to the broader aspects of schooling as an institution, including policies, exams, and curriculum.

While these obligations were originally characterized in the context of K-12 mathematics teaching, here we modify these obligations slightly to attend to teaching in a university setting and do not limit ourselves to the perspective of math teachers. We believe this is appropriate for examining obligations attended to when making connections between one's own course and other courses, because knowing the perspective of both math and non-math teachers is important for symmetric connections to be built. This changed emphasis leads us to slightly reframe the interpersonal obligations as interpersonal and personal obligations to emphasize any interpersonal contexts, including those outside the classroom with colleagues and self-reflection on one's obligations to one's own work-life balance and mental health needs.

Methods

Data was collected from four focus group meetings of ten faculty at one regional university in Spring 2023. Two meetings were held in February and two in April. Each participant was intended to participate in one February and one April meeting, but two participants were unable to attend in April. Gender-neutral pseudonyms, departments, and which meetings were attended are in Table 1. Faculty were solicited from those who completed a survey on their background and perceptions of connections between their courses and mathematics. In the focus groups, each question was asked to the group and each participant was given an opportunity to respond. After everyone had responded, everyone was given an additional opportunity to respond to what others had said. Questions focused on perceived connections between their course and other courses, supports used and desired for making connections, the connections between their courses and math, and supports they suggested or desired for helping students struggling with math content or skills. The focus groups were audio and video recorded and transcribed prior to analysis.

Table 1. Participants' backgrounds and meetings attended.

Pseudonym	Department	February Meeting	April Meeting
Addison	Earth, Atmosphere, and Environment	B	B
Bergen	Curriculum and Instruction	A	A
Carey	Physics	A	A
Darien	Mathematics	B	A
Elliot	Earth, Atmosphere, and Environment	B	A
Freddie	Mathematics	A	A

Gayle	Mathematics	B	none
Harper	Computer Science	B	B
Indigo	Leadership, Educational Psychology, and Foundations	A	B
Jun	Mechanical Engineering	B	none

Data was analyzed by two researchers who coded independently, then discussed and came to consensus on each section of the transcript. We did not enter analysis with a codebook, but used the notion of obligations to guide what we attended to. Both researchers open coded the two February meetings in alignment with descriptive coding (Saldaña, 2016), came to consensus on a codebook, recoded transcripts in alignment with the new codes, and came to consensus on coding. We then, after minor adjustment, coded the two April meetings, added new codes as needed, and came to consensus. Finally, we classified the codes into obligation categories, using three of the obligations of Herbst and Chazan (2011) directly and a modified version of the fourth. This process aligns with codebook thematic analysis (Braun et al., 2019), as we had some sense of the categories but not the particular codes we would use when entering analysis, and had the flexibility to add codes and categories to capture new ideas as analysis progressed.

Results

We present results according to alignment with each of the obligations: Disciplinary, Individual, Interpersonal and Personal, and Institutional. Codes are italicized.

Disciplinary Obligations

Disciplinary obligations in this study manifested as participants' desire to teach the content of their discipline, though this could hinder or assist making connections to other courses. The instructors agreed on the *importance of connections* across content. For example, Bergen stated, "I think it really behooves us as professors, as instructors to make those connections, because if we don't, then we're really not making it relevant to our students…. all the different topics, the fields connect." The instructors also discussed the importance of *showing students connections*, as students can struggle with finding the connections on their own. For instance, Freddie noted:

> …they don't see the connections. They've seen that trig; they've seen the quadratics. But outside of maybe a question at the end of a section, at the end of a unit....in math class…they're focused more on the math rather than the physics. And then when they get to you, it's like "Oh, wait. I know the math. I just got to figure out that physics equation that my math teacher gave me. Where does that come from?"

In addition, Addison recalled student feedback about examples that stated, "I wish those types of examples were in calculus. It didn't make sense why I was learning this".

Instructors also noted hindrances in terms of student knowledge. One issue was that *students had not seen content* required for their course. As Freddie noted, "The problem with the students who are taking that class, they've never seen parametric equations. They've never seen the idea that time controls this, the horizontal and vertical. No clue about it." Another perceived issue was that *students do not retain knowledge* from previous courses. Carey noted: "You can tell there's a light that's like 'Oh, yeah. I've seen that. I remember trig functions at some point.' But how much they remember about trig functions and inverse trig function[s] and that sort of thing is another question." Relatedly, participants perceived *students as not having conceptual mastery of the skills* required from previous courses. In an algebra-based physics course that Carey teaches, they noticed, "So in principle, it's stuff that they should have been exposed to, at least in high school, but it's really nothing new…. I think one of the challenges I'm having is that they don't have the mastery, so they're – in a company of mathematicians, I hate to say that math is a distraction. But it's kind of a distraction from the physics." Instructors also stated actions they take to help combat these issues, such as *helping students review*. Harper shared:

> And so it's never the case, where you walked into a class and everybody knows every single thing from every single prerequisite. And sometimes you have to take a little detour. But you can't spend a lot of time there, simply because that's not the course.…If they're really largely, all of them, wholesale not getting it… then there's no point in going on with the lecture. You have to take a detour in real time and try to give them a week's worth of whatever math in about 15 minutes, hopefully, as a refresher.

Individual Obligations

We classified as individual obligations anything that pertains to the student's mathematical identity and their needs going into their classes. Many aspects related to affective considerations, such as *students being anxious about math*. Bergen said of their students, "They are still terrified of math, oftentimes more so after taking the math classes." Relatedly, Elliot claimed that *helping students reduce anxiety* should be a goal of math courses: "So on the philosophical side, I think that one of the goals of the math classes should be to help students get over their fear of math, because many of them come in with that fear and they are disinclined to pursue occupations, majors, whatever, that have any kind of quantitative aspect to them." Others, like Darien, taught particular tools to reduce anxiety: "We go over developing growing mindset, trying to get them to know that math is for everyone and there is not people that are good or bad at mathematics." Darien also relayed a time that focused on community building and *motivated their students*:

> I had an intervention…So instead of going into content that day, we just sat.…And I just told them, 'What do you want from me?' ... Because I am not going to be your teacher this whole time, during these four years….And they were like, 'Oh yeah. If we tell you to change something, it's not going to affect us directly.…We have to learn how to move to other courses. We have to improve our skills. We have to study more.' So they were… brainstorming of what they could do to just be better at math. And I've been having good outputs off that: attendance was better, and they were more motivated…after that.

Other aspects related to knowledge of students. Addison noted *student backgrounds are sometimes unknown* based on students transferring and lack of knowledge of courses in other disciplines: "I learned from googling precalc, so I thought it was all algebra, but I was wrong. There's some precalc in there too. Yeah but it is hard when we have transfers and not everyone has to take the full calculus sequence because we don't require everyone to take it." Others, like Indigo, built on their *knowledge of students' backgrounds*: "because most of my teachers in training are not statisticians and not trained in that, I take that as my job to inform them."

Finally, some topics related affect and content, such as the *need for students to be motivated to do the work*. Elliot said, "And I feel like they get a lot of, they're told that this is a mathematical relationship between variables, but they don't grasp, like, 'What are the variables that I might actually work with, and why do I care about all this?'" Darien seemed to suggest that student motivation is misdirected at procedural rather than conceptual understanding: "We are trying to help them understand concepts, but they don't want to because they think that that's not important…it's like, 'Tell me what I need for those skills that I need so I can pass my next calc courses.'" Elliot suggested *building community* with alumni to impact motivation:

> Whatever discipline you're in, having students exposed to people who actually use math in a career… I do think there are more than a few who don't think it's important for

where they see themselves going.…the more they can see people that they can model and see 'I could be like that. That person is like and was like me.' Because when employers come in, a lot of time, they're alumni. They will literally say, 'I was in that chair. I sat in that chair in this class, and I felt exactly the same way you do…this is where I am now.'

Interpersonal and Personal Obligations

We characterized interpersonal and personal obligations as shaping classroom discourse and interactions outside the classroom as well as one's own views. When instructors are *not familiar with other course content*, that can impact assumptions. For example, Addison states:

My hydrogeology class is a math class and that's how I start my class, by saying it is. And I'm a little embarrassed to say, yeah, I've never really spoken to math teachers about what I teach in it. And to the point when I did your survey, I google[d] to find out what classes some of those concepts were taught in because I couldn't remember.

Additionally, Addison noted the impact of their *personal experiences with course material* and a career outside academia on their teaching: "I had to take through Calc 3 when I was an undergrad and forgot it, a lot of it going on. And I didn't really need it in the sense of knowing those foundations. I worked after my bachelor's degree and most students are just going to go out and work. They don't need to know all that specifics." Based on Addison's experience of not using advanced math in their career, they saw limited value in their students having that knowledge. Instructors' *limited time* affects how much they can put into a course. Darien shared their experience with a new course: "I don't feel I'm doing a great job, especially because I'm always running out of time…So I come up with examples that are similar to a textbook…, just to explain the concept and continue with the next class." Freddie noted a lack of familiarity with colleagues: "I guess I'm still the newbie here. I don't know much of anybody." Not knowing colleagues meant they *did not know who to talk to* about connecting content.

However, instructors did not exclusively note challenges. Freddie was *familiar with* math and science K-12 *content* and stated, "I do the proportions that they're going to mostly see in the book, but I also make sure I fold in some of the gas laws…Charles's law or Boyle's laws." In some cases, like Freddie's, instructors may already know other course information. For those that do not, Elliot recommended ways to *gain information about other courses*: "I've thought for years that mathematicians should maybe come into our classes and say, 'All right, here's the nuts and bolts of this,' or the people who do the applied math should provide examples for the people who are teaching the math and say, 'This is how we do this.'" Others noted positive ways their *personal experiences of courses* impacted instruction, such as Carey:

For introductory physics, one of the things I try to do…is to try and use math terminology that I think they would be familiar with from a math class…so the slope of your position-versus-time graph is the velocity. So we look at our position-versus-time graph and we start, 'Oh, if I want to calculate the average velocity, how do I do that?' Then I look at this and it's like, 'Oh, we measure how much this way. Oh, this is like a rise. And now we measure how much this way. And this is like a run. And, oh, if we take the rise over the run, right, oh, that's the slope, right?' And with some of the trig stuff…I specifically use term opposite and adjacent and hypotenuse and similar sort of terms that hopefully they'll be familiar with from math and might start to engage their memory a little bit.

Instructors also noted *time saving strategies* they can use. One of the most common strategies was looking online for resources. Carey had knowledge of a research field that would be likely to have resources: "Physics for the Life Sciences basically is this whole thing, and there's people out there who've had curricula and how they set things up." Additionally, Bergen shared advice on how to *build relationships with colleagues* to encourage collaboration:

> It's interesting that the advice I was given when I first got here 13 years ago. Department chair at the time, he said, 'I want you to join [committee].'…And that was one of the best decisions or… the best voluntelling…Because then I got to…meet people from all over campus...and that's the best way to make you feel like you belong some place.

Institutional Obligations

We characterized institutional obligations as attention to institutional policies impacting promotion and curriculum; most of these obligations hindered making connections across courses. Many instructors noted that *finding others who want to collaborate was difficult* and in many *ways the university did not seem to value the need for connections*. Addison emphasized the need for working with others to be incentivized: "I have to not get dinged for taking the time to reach out to people because, yeah, unfortunately, research is really the key." Similarly, Elliot stated, "Until I see or feel that there's a lot of incentives to do that, and that would also require…changing the whole structure, not of departments but how the university sees these classes." *Others* also need to *value collaboration for connections to be built*, as Carey experienced: "Several of us in the physics department tried to have this conversation with the biology folks.…they sent over their advisor, and basically, he said, 'Oh, they just need to take the MCAT,' which wasn't very helpful for us.…at least based on what he said, physics has no relevance to biology other than doing well on the MCAT." University policies also seemed to encourage competition rather than cooperation. This was especially impactful in *course design* and *credit hour requirements*. For example, Darien and Addison discussed whether a new or different calculus course should be a prerequisite for Addison's course:

> *Addison:* If I didn't let students who either were co-taking calculus or had failed and they're going to retake it, take my class, I wouldn't have a lot of students.…So I have to show the applied and I'm not sure I would be good at teaching those foundational things beyond… "Don't you remember this? It's okay if you don't. We're going to keep going."
>
> *Darien:* Do you think that an applied calculus class will help with that as a prerequisite? Because we don't have an applied class right now. We just have a business and social science class.
>
> *Addison:* In principle, yes. Do I want to make them take another class? No.

In addition to limiting prerequisites from other disciplines to save space for major courses, starting *new courses* could be extremely *competitive*. Harper shared:

> The single most impactful thing that the university could do in order to help the issue you raised is to change the manner in which new courses are being developed or proposed. It's not designed as such but what it actually is is a land rush. It's the first one to market gets to claim the course…That's not thoughtful, it's competitive.

Finally, when creating requirements for courses, instructors build on their own personal experience, but *courses change over time*. For example, consider the following conversation:

> *Harper*: Okay. Do they do proofs in Calc? Calc 1 and Calc 2?
>
> *Interviewer*: No.
>
> *Harper*: Things have changed since I took Calc 1 and Calc 2.
>
> *Gayle*: Depends on who teaches Calc a little bit.
>
> *Harper*: Which is to say that a lot of time has passed since I took Calc 1 and Calc 2, but things have definitely changed.

On the somewhat positive side, Gayle noted they had *collaborated* with Carey *on a co-requisite course*, but also acknowledged some challenges: "For freshman engineering students…

usually like the Calc schedule gets all wonky because we'll end up doing either Rolls [Theorem]… in week 2 or something just so that they have it and like they can then use that for kinematics … so they apply it and do physics labs and things like that." Gayle noted that this arrangement between physics and calculus could lead to an unusual calculus schedule, where applications that typically follow differentiation techniques instead are addressed early in the semester, though this was done to benefit students' understanding in their physics course.

Discussion

This study examined disciplinary, individual, interpersonal and personal, and institutional obligations as perceived by faculty, especially as they support or hinder making connections between courses. Participants highlighted disciplinary obligations as motivation for them to make connections but noted obstacles like a perceived lack of student knowledge or mastery, preventing students from fully understanding the connection or preventing faculty from attempting to make connections. Individual obligations manifested through faculty's attention to students' content backgrounds and affective needs. The supports and hindrances in this case mirrored each other, as faculty highlighted anxiety as a common issue but also shared ways to address this; similarly, they highlighted both a lack of knowledge about students' backgrounds and ways this knowledge could be leveraged if known. Interpersonal and personal obligations emphasized the instructors' knowledge and relationships and their impact on making connections between courses. In these obligations also, supports and hindrances mirrored each other, with some participants extolling the power of connecting with colleagues while others wondered how to make those personal connections; similarly, faculty's prior experiences with courses could either incentivize or prevent making connections. Finally, institutional obligations highlighted the need to attend to existing policies. In most cases, these obligations served as hindrances to making connections, as making connections is not valued for tenure and promotion and policies fostered competition between departments over course design and maximizing credit hours.

We believe applying the lens of professional obligations (Herbst & Chazan, 2011) to our data provides three useful insights. First, our participants were likely a best-case scenario for making connections between math and other areas; they were willing to take time to attend focus groups and saw value in making connections. However, even they highlighted hindrances to connections across all four types of professional obligations, especially institutional obligations. Second, multiple instances arose where faculty did not see the purpose of having certain prerequisites, whether because they viewed the information as irrelevant for their students, likely to drive students away from their own courses, or unlikely to be remembered when needed in subsequent courses. Considering calculus's current role as the gateway to STEM (Bressoud et al., 2015) and other studies with faculty questioning the importance of math courses for learning STEM content (e.g., Rupnow et al., 2023), such perceptions from other disciplines are important to consider to ensure math courses are performing their expected role in the curriculum and valued by other disciplines. Finally, our participants had almost exclusively negative things to say about the impact of the institution on the making of connections. Some policies may be difficult to change (e.g., activities valued for tenure, budgetary formulas) whereas others would require less effort (e.g., providing collaboration spaces for likeminded faculty). We encourage future work on the impact of these policies and how they could be changed to support connections across courses.

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