Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

ORIGINAL ARTICLE

Bridging Science and Language Development Through Interdisciplinary and Interorganizational Collaboration: What Does It Take?

Daniella Molle*, Weiqiong Huang

Wisconsin Center for Education Research, University of Wisconsin–Madison

***Corresponding Author:** daniella.molle@wisc.edu

ABSTRACT

This study addressed the intractable issue of ensuring that all students, including those who are linguistically and culturally diverse, have access to high quality science education. We explored the efforts of two organizations in the United States (one that supports science teachers and one that focuses on language development) to design resources that can inform science instruction for multilingual learners. We used Bronstein's (2003) framework for interdisciplinary collaboration to shed light on the institutional, program, and interpersonal factors that defined and helped sustain the collaboration between the two organizations. The findings showcase what it takes to integrate equity, science, and language development considerations in resources designed to inform content-area instruction for multilingual learners. The paper adds to the nascent literature on the role of interdisciplinary collaboration in supporting the science education of multilingual students and is unique in its exploration of both the process and the product of this collaboration.

KEY WORDS: content and language integration; interdisciplinary collaboration; multilingual students

INTRODUCTION

There is accumulating evidence that multilingual students[1] in the United States have limited access to rigorous science instruction. Multilingual students are underrepresented in science, technology, engineering, and mathematics (STEM) fields in college and in the workforce at a time when the demand for professionals in STEM fields is unmet and increasing (National Academies of Sciences, 2018). A key reason for this underrepresentation is a persistent opportunity gap in STEM education for multilingual youth; multilingual students are often excluded from engaging fully in science instruction and have limited access to STEM courses (e.g., Callahan and Shifrer, 2016). Scholars have argued that one powerful way of addressing this inequality is the design of high-quality resources that support science teachers in meeting the needs of multilingual children and youth (Lee, 2019).

This paper discusses one such resource, the *Design Principles for Engaging Multilingual Learners in Three-Dimensional Science* (MacDonald et al., 2020). This resource was published by the Making Science Multilingual (MSM) program. The program is a joint endeavor between two organizations: One that serves science educators (the National Science Teaching Association, [NSTA]) and one that supports teachers of multilingual students (World Class Instructional Design and Assessment [WIDA], which offers language standards, language assessments, and professional learning to educators working with multilingual children and youth). The MSM program emerged in response to the commitment of both organizations to promote equitable science instruction for all students and especially multilingual learners. The integration of three-dimensional science learning (NGSS Lead States, 2013) and language development is at the heart of MSM's mission and is reflected in MSM's leadership structure. MSM is co-led by an expert in science education and an expert in language education.

In this paper, we examined the interorganizational and interdisciplinary collaboration that gave rise to the MSM design principles. The purpose of the study was to shed light on the processes that contributed to the robust integration in one document of priorities related to equitable instruction, language development, and science education. The research question guiding the study was: What factors enabled and sustained the interdisciplinary and interorganizational collaboration that yielded the design principles? The paper adds to the nascent literature on the role of interdisciplinary collaboration in supporting the science education of multilingual students (Lee et al., 2019; Moore et al., 2015) and is unique in its exploration of both the process and the product of this collaboration.

1. We use the terms *multilingual youth* and *multilingual students* to refer to students officially designated by school districts as English language learners or English learners. While most of the students are bilingual, many of them use more than one language in addition to English.

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

LITERATURE REVIEW

Interdisciplinary Collaboration

Before we explore the process of interdisciplinary collaboration, it is important to describe what we mean by it. *Interdisciplinary collaboration* is a process that involves professionals from different disciplines and aims to foster the integration of perspectives, concepts, theories, methods, and so on from these disciplines as a way to promote more innovative and holistic solutions to complex problems (Cheng et al., 2019; Tinnell et al., 2019). Another, related term used in some of the literature is *transdisciplinary collaboration*. According to Khoo et al. (2019), the difference between inter- and transdisciplinarity lies in the extent to which the integration of different disciplinary tools and practices contributes to the creation of something novel. While we believe that the weaving together of science and language learning fosters the emergence of new approaches and practices related to the education of multilingual youth, we prefer to use the term *interdisciplinary* because it is more commonly used and so more familiar to readers.

Factors that Shape Interdisciplinary Collaboration

Interdisciplinary collaboration is a complex process and scholars have identified a number of factors that shape it. One of these factors is the quality of interpersonal relationships among the partners. Interpersonal relationships that support collaboration are egalitarian and involve shared leadership and goals along with mutual trust, respect, and commitment to the collaboration (Johnson et al., 2020; Summers et al., 2019). These types of relationships are essential for navigating the conflicts that inevitably arise as people with dissimilar paradigms and priorities work together. Relationships of trust and respect can inspire the collaborators to construct conflict as an entry point into each other's perspectives (Gunawardena et al., 2010). These relationships can also support partners in viewing the differences among them as assets they can draw on to generate innovative solutions to difficult problems (Cheng et al., 2019).

Another factor that influences interpersonal collaboration is the nature of the collaborative process itself. Scholars have suggested that reflection on the process of collaboration can help partners keep it on track (Vanasupa et al., 2012). This type of reflection can support the emergence of a shared vision for the collaboration among the partners and create a space in which the partners can come to understand their dissimilar mental models and ways of constructing knowledge (Vanasupa et al., 2012). The shared understanding can in turn support the partners in integrating, and not merely including different disciplinary perspectives in their work (Neill et al., 2017).

A third factor that affects interdisciplinary collaboration is the infrastructures that are in place to support the process. Successful collaboration depends on institutional support (Summers et al., 2019) and strong leadership (Tiongson, 2018). Structures and processes related to management and communication help ensure that the collaboration receives the institutional support it needs in the form of financial and personnel resources (Löfström, 2010). An effective leadership structure helps the partners smoothly navigate the different steps in the collaboration process (such as setting group goals and identifying priorities) as well as successfully address challenges as they arise (Tinnell et al., 2019). Interdisciplinary collaboration is also supported by people who build bridges among the partners and serve as mediators (Gunawardena et al., 2010), brokers (Bouwma-Gearhart et al., 2014), or facilitators (Khoo et al., 2019).

In addition to highlighting factors that foster interdisciplinary collaboration, the literature sheds light on processes and practices that present challenges to it. One such process is related to institutional divisions of labor that create power differences. Hierarchical relationships among the partners can constrain their commitment to the collaboration, opportunities to craft shared goals, and ability to promote a more bidirectional relationship (Moore et al., 2015). Another obstacle to collaboration has to do with the bodies of knowledge of each discipline. Boundaries that arise from the specific knowledge and skills of the different disciplines as well as their dissimilar values and practices can make interdisciplinary collaboration challenging (Wannenmacher, 2020). Another factor that imperils interdisciplinary collaboration is the nature of the interpersonal relationships among the partners. Collaborators may have different work styles and divergent priorities (Tinnell et al., 2019), and teams may experience lack of clarity about roles and absence of team cohesion (Retrouvey et al., 2020).

This brief overview of the literature highlights some of the features of successful interdisciplinary collaboration and points to potential pitfalls for partners working across disciplines. The studies reveal both the challenging nature and the promise of this type of boundary-crossing work. This study contributes to the literature by addressing both the process and the outcomes of interdisciplinary collaboration (Johnson et al., 2020). The paper focuses on interdisciplinary efforts to support the educational success of multilingual youth.

THEORETICAL FRAMEWORK

Our exploration of interdisciplinary and interorganizational collaboration is based on Bronstein's (2003) conceptual framework. Bronstein is a scholar in social work, but her model of interdisciplinary collaboration has been used across fields, including in higher education (Tinnell et al., 2019) and special education (Palladino, 2011).

Bronstein's (2003) model consists of two parts: Components that constitute interdisciplinary collaboration and influences on interdisciplinary collaboration. The components are: (a) *Interdependence*, which refers to the collaborators' understanding of their complementary roles and includes the structures they put in place to communicate and work together; (b) *newly created professional activities*, which are durable collaborative structures that enable the partners to build on each other's expertise; (c) *flexibility*, or the blurring and shifting of roles as necessary to accomplish shared goals; (d) *collective*

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

ownership of goals, which refers to shared responsibility in defining and working toward goals and shared involvement in decision-making; and (e) *reflection on process*, or paying attention to the collaborative process itself.

Bronstein's (2003) model places the components of interdisciplinary collaboration in context by addressing a range of factors that shape the process. She identifies the following influences on interdisciplinary collaboration: Professional roles, structural characteristics, personal characteristics, and history of collaboration. The partners' *professional roles* affect collaboration because a strong sense of professional identity enables each partner to bring their unique disciplinary perspective to the collaboration. That unique perspective, combined with a strong commitment to the interdisciplinary work, can enable the collaborators to bridge their respective fields and find a shared language that reflects the values and practices of both disciplines. *Structural characteristics* affect interdisciplinary collaboration because any collaborative effort depends on administrative support (including financial commitments) and time and space for the collaboration to occur, among other factors. Personal factors also shape collaboration. Bronstein highlights two: *Personal characteristics* (including trust, respect, and effective communication) and *history of collaboration* (or the partners' earlier experiences of engaging with colleagues across disciplines).

Taken together, the components of and influences on interdisciplinary collaboration in Bronstein's (2003) model support researchers in exploring the mechanisms that help establish and sustain interdisciplinary collaboration over time. This exploration enables a deeper understanding of the evolution of the collaborative process and helps explain how certain processes contribute to particular outcomes of the collaboration.

SETTING AND PARTICIPANTS

The participants in the study were the two co-leaders of the interorganizational MSM program: David Crowther and Rita MacDonald. They were recruited following an informed consent process approved by the University of Wisconsin–Madison Institutional Review Board, and we are using their real names with their permission. Crowther is a science teacher educator with both a national and international reputation who has a longstanding professional interest in the science education of multilingual youth. He was the president of NSTA in 2017–2018. MacDonald is an associate researcher and language expert at WIDA with extensive experience in developing instructional resources for STEM teachers of multilingual students.

With the exception of interviews with the co-leaders, all other data for the study were generated as the co-leaders engaged in the activities of running MSM and working toward its deliverables. WIDA commissioned the study because it could inform future decision-making about partnerships with other organizations. The two authors collected and analyzed the data but were otherwise not directly involved in the activities of MSM. All research-related activities were carried out in accordance with a research protocol approved by the Institutional Review Board of record.

DATA COLLECTION AND ANALYSIS

The analysis is based on a range of data collected by the authors between February 2019 and February 2020. We focused on Year 1 of the program because it was the time during which the program was established and its approach to language and content integration was defined. The formative 1st year thus offered a fertile ground for the exploration of the process of interorganizational and interdisciplinary collaboration. In 2021, the program is currently in its 2nd year and its work focuses on the collaborative development of teacher resources.

The data we collected include audio recordings of regular meetings between the two co-leaders, notes from face-to-face meetings between the co-leaders, documents related to administrative processes and reporting (such as mission and vision statements, steering committee meeting notes, and an end-of-year report), and interviews with the co-leaders (two with MacDonald and one with Crowther).

We conducted the data analysis in stages. We used the audio recordings to write detailed summaries for all the virtual meetings between the co-leaders. The summaries included the ideas shared by the co-leaders and reflections by the researchers. The creation of the summaries made coding more manageable and increased our familiarity with the data, since each summary required repeated and closes listening to the recordings. The summaries were first generated by the second author and then revised by the first. Based on the summaries, we constructed a timeline of key program activities, tasks, and products. The timeline also included a list of topics that the co-leaders discussed when they met.

We used the qualitative software NVIVO to conduct thematic coding of the summaries and other artifacts collected for the project (Allen, 2017). Our thematic coding was based on concept codes related to the research question and the relevant literature (Table 1). We used constant comparison (Gibbs, 2007) to refine codes, create new codes, and merge existing codes as we worked across data sources. We wrote up a description of our findings as a WIDA report (Molle and Huang, 2020). We shared a draft of the report with the two participants (Crowther and MacDonald) for member-checking. Their feedback confirmed the validity of the findings and added background information to some of the points discussed. We then used Bronstein's (2003) conceptual framework to deepen and expand the analysis.

RESULTS

This section uses Bronstein's (2003) conceptual framework to explore the interdisciplinary collaboration that was at the heart of the MSM program. The purpose of the analysis was to explain

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

how different factors contributed to the robust integration of equity, science, and language development considerations in the MSM design principles (MacDonald et al., 2020).

Components of Interdisciplinary Collaboration

Interdependence

The interdependence between science and language educators in promoting equitable science instruction for multilingual youth was the principal motivation behind the collaborative relationship between WIDA and NSTA. The formation of the MSM program as a joint endeavor was necessary for both WIDA and NSTA because it assisted them in carrying out their missions. NSTA is committed to promoting "excellence and innovation in science teaching and learning for all" (NSTA, 2020, para. 1) WIDA strives to advance the "academic language development and academic achievement" of multilingual children and youth across the content areas (WIDA, 2020, para. 5). A shared goal of both organizations, therefore, is the development of high-quality educator resources that support the equitable engagement of multilingual students in science. The development of such resources would be impossible without the long-term collaboration among science education and language development experts that MSM enabled. Leaders from both organizations realized this interdependence and committed considerable resources (funding as well as staff time) to support MSM's activities.

The two MSM co-leaders were also deeply committed to working together. As MacDonald put it, Crowther's "genuine receptivity to working and learning together" impressed her and inspired a feeling of trust and connection (MacDonald, interview, March 7, 2019). The openness to interdisciplinary collaboration was evident in the egalitarian relationship among the co-leaders and the structures for communication they put in place. Both co-leaders approached their collaboration with a sense of respect for the other's expertise and an awareness of the limitations of their own knowledge. They distributed work such that each of them took the lead on tasks that had to do with their own area of expertise. At the same time, they solicited each other's opinions on content they created and decisions they made related to these tasks. In Excerpt 1, for instance, Crowther explained his vision for how the WIDA language resources fitted within a presentation on inquiry in science. The co-leaders' openness to learning and respect for each other's expertise enabled them to engage in shared meaning-making, learn from each other, and collaboratively design resources in which they both felt invested.

Table 1: Sample codes and illustrative excerpts

Codes	Sub-codes	Coded excerpt from a summary
Roles		
	• Insider	MacDonald will ask when WIDA developers might be available, and Crowther will reach out to NSTA's president to see if there are any additional developer resources from NSTA
	• Project manager	They have 5 weeks to prepare the project charter and submit it to WIDA for internal approval
Collaboration		
	• Vision for the program	MacDonald thinks their role is to keep their hands on the visioning, such as what the 3- or 5-year plan is, and how they make sure it's appropriately situated in a changing landscape
	• Messaging	Crowther sees the pedagogical principles as a foundation for a document that helps every product by NSTA "embrace language learners to some degree"
Language-content connections		Crowther: If they can show how the WIDA resources tie to the 5E that can serve as a baseline from which people can easily move to other philosophical frameworks, such as CER

The co-leaders put in place structures that supported their collaboration over time. These structures included both virtual and in-person meetings. The co-leaders held virtual meetings on a regular basis: Between 1 and 4 times a month. The meetings gave the co-leaders opportunities to update each other on activities related to the program, discuss emerging issues, and make decisions about upcoming activities (such as conference presentations).

The virtual conversations were essential but insufficient for interdisciplinary collaboration. The co-leaders realized that they needed opportunities to work together in person to accomplish challenging conceptual work. The in-person meetings enabled them to "get away from their task list" and "build a history of working together" (Crowther, interview, April 19, 2019). During the 1st year of the program, the co-leaders met face-to-face 4 times for 2–3 days. The conceptual work they accomplished involved science and language integration more broadly, and more specifically the development of models that bridge language resources developed at WIDA with pedagogical approaches familiar to science teachers (such as the 5E model for science instruction,

Excerpt 1: Co-constructing meaning (virtual meeting, May 8, 2019)

Crowther:	You've got strategies, you've got discourse moves. Many teachers are going to put kids into teacher-to-student discussions and then they very shallowly put students-to-students in discussions. So once again, I think that what you've got developed here is really great
MacDonald:	So (the WIDA resources) are tools to activate the small group work, to really deepen the small group work for the sake of reasoning
Crowther:	And we take this particular approach to say, "if you really want to impact the ability to build language in your students, then they have to have more time to talk to one another"
MacDonald:	About ideas
Crowther:	And one of the ways that science and language do that together is through inquiry-based teaching

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

see Bybee et al., 2006). The in-person meetings created much needed opportunities for in-depth, collaborative meaning-making and enabled the co-leaders to expand their knowledge of each other's fields. This expanded knowledge in turn supported their virtual interactions and informed the resources they collaboratively developed.

New professional activities

The MSM program itself is an example of a durable collaborative structure that enables interdisciplinary collaboration. The program was formally established in April 2019, though WIDA began laying the groundwork for the program as early as January 2019. We discuss the interorganizational support structures that sustained the program in greater depth in section 6.2 Influences on Interdisciplinary Collaboration. Here, we focus on another durable structure that fostered interdisciplinary collaboration: the science team.

The co-leaders began planning to create a science team early in the life of the MSM program. Such an interdisciplinary development team did not yet exist either at NSTA or at WIDA. Creating the team meant that the co-leaders needed to determine its purpose, rationale, activities, and deliverables. They had to clarify to each other and the team itself what the science team members were expected to contribute.

The co-leaders were committed to involving other staff from WIDA and NSTA in the activities of the program for two main reasons: (a) Their own expertise was insufficient for the accomplishment of the program's mission, and (b) the involvement of other staff would increase the ownership of and commitment to the program. To develop robust resources for science teachers of multilingual students, the co-leaders needed the collaboration of colleagues who had experience integrating science and language in teacher professional learning. Three WIDA staff members with such expertise joined the science team. In addition, the co-leaders sought partners whose work focused on equity in science teaching. A faculty member with this expertise who is unaffiliated with the University of Wisconsin agreed to serve on the team. The development of resources by two organizations also depends on the active involvement of representatives from both. Two NSTA staff joined the science team to ensure that NSTA's priorities and commitments were reflected in the resources developed by MSM. Finally, the program required technical expertise related to creating online teacher resources. As a result, a WIDA instructional designer joined the team.

The existence of the science team ensured that the program represented interorganizational collaboration rather than the joint work of two individuals. As MacDonald put it, "we (the co-leaders) have not wanted to do a lot of conceptual development until we had a whole team. Then … we will set a series of meetings where … we'll decide on some foundational readings and discussions and enter into some shared learning that way, and then evolve into developing an approach we want to take" (in-person meeting, April 18, 2019). The science team enabled the co-leaders to act as facilitators and distribute both sense making and decision-making.

The science team met 8 times between September 2019 and January 2020. The team's composition made possible the interdisciplinary collaboration that MSM was created to foster. The work of the team culminated in the publication of the MSM design principles in February 2020. Most importantly, it is a structure that still endures. In the 2nd year of the program's existence, the science team continues to be at the center of MSM's development work.

Flexibility

The third component of interdisciplinary collaboration in Bronstein's (2003) framework refers to the blurring of roles among partners. This phenomenon was most visible in the ways in which the MSM co-leaders interacted around the materials they were co-designing. Although each co-leader assumed the role of a subject-matter expert, from the beginning of their collaboration the co-leaders asked questions and contributed insights about each other's areas of expertise. For example, the analysis of a debriefing conversation after the co-leaders' first face-to-face meeting indicates that Crowther provided feedback on WIDA instructional materials that helped increase the prominence of interactive uses of language in these materials. By the same token, MacDonald's feedback helped inform the science activities that the co-leaders included in conference presentations (Excerpt 2).

The blurring of roles enabled the co-leaders to continuously learn from each other and deepen their shared understanding of what content and language integration could look like in practice. This understanding informed their facilitation of the science team meetings and the ideas they contributed to the MSM design principles (Excerpt 3).

Shared ownership of goals

The two co-leaders of the MSM program engaged in a collaborative relationship built on mutual trust and respect. This relationship contributed to share responsibility in defining and working towards goals as well as to share involvement in decision-making. Excerpt three offers an illustration of the co-leaders' collaboration in determining the direction of future

Excerpt 2: Flexibility (virtual meeting, January 29, 2020)

Crowther:	I reserve the M&Ms activity for the afternoon as a placeholder …
MacDonald:	Do you know, something that continues to trouble me about the [M&Ms activity] though is that I am struggling to think, how does that connect– That doesn't seem to me to connect to curiosity or people's lives. It seems like this cool activity that people have fun doing, but what in their real life would provoke curiosity about that? …
Crowther:	I agree. I think that connection needs to be developed and I am struggling with that right now. … We do what we did because it got us thinking about it but is it a really good personalized phenomenon that asks a big question? I think we can find something much better

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

Excerpt 3: Shared ownership of goals (virtual meeting, November 4, 2019)

MacDonald:	What I want to get [the science team] talking about is … What are our principles about? What do we choose to have our principles be about? … And I am thinking we are developing principles for the authentic engagement of multilingual learners in science. We don't have to write science principles. We don't have to write equity principles. But we do have to write [about] engagement and language integration. What do you think about that?
Crowther:	I agree and I think that it all revolves around this language-in-use theory that we are drawing on

action. The excerpt shows how the co-leaders worked through their own vision for the design principles that the science team was preparing to create. Excerpt 4 is an example of the kind of negotiation in which the co-leaders engaged when making decisions. The shared process of deliberation helped highlight different priorities: Publishing a book and having enough time to develop professional development modules. Through dialogue, the co-leaders agreed to create a timeline for the book that felt feasible and design modules that aligned as much as possible with the content of the book.

The shared decision-making that the excerpts exemplify remained consistent throughout the 1st year of MSM's existence. This is not surprising given the history that the co-leaders had of working together before MSM was established and the egalitarian relationships they valued and sustained. We discuss the importance of both history and personal relationships later. The collaborative decision-making process helped ensure that both co-leaders made substantive contributions to the activities of MSM and that their personal and professional priorities were reflected in the MSM products.

Reflection on process

Bronstein (2003) argues that reflection on the nature of the collaborative process is an important component of interdisciplinary collaboration. In the context of the MSM program, this reflection reinforced the structures for communication between the co-leaders and informed their choice of collaborators.

The reflection on process revealed the need for face-to-face meetings in addition to virtual ones. One of the key tasks that MSM needed to accomplish was to connect a WIDA framework for content and language integration to pedagogical approaches that science teachers would recognize. Early in Year 1 of the program, the co-leaders integrated the WIDA framework and the 5E model for teaching science (Bybee et al., 2006). Later, they explored connections between the WIDA framework and two other conceptual tools familiar to science teachers in the United States: The claim-evidence-reasoning (CER) approach (McNeill and Martin, 2011) and the science and engineering practices (SEPs) in the New Generation Science Standards (NGSS Lead States, 2013). The co-leaders' reflection on the process of collaboration convinced them that this type of conceptual work could only be accomplished through face-

Excerpt 4: Shared decision-making (virtual meeting, January 6, 2020)

Crowther:	Do you want to not write the book?
MacDonald:	I think I need to think about that. We've committed to doing that. If that's important, then we'll do it. But we've also got to be developing some professional development modules. So it's like where do we rank that along with everything else? … I think if the timeline for the book were generous enough that we could develop the modules, that we didn't have to crank it out quickly
Crowther:	I think we establish the timeline once it's accepted. … I think what I want to do is finish that [book] proposal and get it formally accepted, so that we can then build that timeline
MacDonald:	OK. … So we'll want to be really strategic then about what modules we build
	…
Crowther:	So I'll start working on [the proposal] and I won't send anything in until you review it
MacDonald:	As long as we get to set the timeline, then that's great
Crowther:	I agree

to-face meetings in which they worked together to integrate science and language learning. The content and language integration process was too complex for one of them to tackle individually and then solicit the other's feedback during virtual conversations.

The co-leaders' reflection on process also informed their efforts to involve others in the development work of the MSM program. The co-leaders felt that the emphasis on equitable student participation in sense making was central to any resources MSM developed (Excerpt 5). This priority guided their search for a suitable partner and led to the selection of a faculty member whose work focuses on equitable science instruction. This person became the only member of the science team who was not affiliated with either WIDA or NSTA. In addition, MacDonald felt that many of the conversations about science and language integration required a deeper understanding of science than she had as a linguist. She advocated for another WIDA colleague who was a former science teacher of multilingual youth to begin playing a more prominent role in the decision-making and resource development processes of MSM. This colleague's involvement in MSM gradually increased in Year 1. In Year 2, she became Crowther's co-facilitator in professional development offerings related to MSM.

The co-leaders' reflection on process enabled them to accomplish challenging conceptual work and to recruit the collaborators they needed to support the robust integration of equity, language development, and science learning in the resources that MSM produced.

Influences on Interdisciplinary Collaboration

Professional role

Working across disciplines contributes to innovation (Khoo et al., 2019; Klaassen, 2018) and at the same time requires

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

the bridging of different ways of talking and thinking about the world. In the context of the MSM program, it was the bridging of science and language education and the integration of science and language learning that required recurrent opportunities for shared meaning-making over the long term. The complexity of bridging disciplines can be seen in how often the MSM co-leaders discussed the relationship between content and language. As Table 2 illustrates, the topic of content and language integration remained relevant throughout Year 1 of the program. The co-leaders explored conceptual questions related to science and language integration, such as how to connect pedagogical models in science (5E and CER) to language resources that WIDA was developing, and what the role of language specialists may be in science instruction and assessment. The co-leaders also engaged in more practical discussions about how their emerging shared view of content and language integration would be reflected in different program deliverables, including the MSM design principles.

Excerpt 5: Reflection on process (virtual meeting, April 24, 2019)

MacDonald:	I want to work with someone who understands that equity isn't just about the languages or scaffolding learning. It's what you do with students' ideas: how do you listen to them, how do you take them up, how do you follow them, how do you respect them. … We read … that series of articles… where rigor came not from the curriculum but from how teachers tracked and used student ideas. And that's what the (WIDA framework) is all about and I'd like to strengthen that connection
Crowther:	If you think we should go in a different direction, I'm completely open to that
MacDonald:	Thanks for that. I'll poke around and see (who) has that. … See what you think, too. We don't have to decide now

Structural factors

The MSM program is an interorganizational enterprise. As such, its existence depends on the administrative support it receives from WIDA and NSTA. Both organizations supported MSM's activities through the allocation of staff time and other financial resources (such as funding the co-leaders' conference travel). The financial commitments by both organizations made the work of the program possible and signaled a shared commitment to its mission and products.

To sustain this institutional support, the co-leaders put in place structures that were specific to each organization. At WIDA, the co-leaders formed a steering committee, which included heads of different WIDA departments and met once every few months for a total of five meetings during year 1 of the program.

Table 2: Key topics discussed during co-leader meetings

Meeting dates	Relationships between content and language	WIDA/NSTA relationship	Questions about the program	Conference presentation preparation	Science team	Resource allocation
2/7–9/19	x					
3/20/19			x	x	x	x
3/27/19		x	x			x
4/18–19/19	x	x		x	x	x
4/24/19		x	x		x	
5/1/19	x	x	x			
5/8/19	x	x	x			x
5/15/19			x			
5/22/19	x			x		
7/10/19	x	x			x	x
7/25/19	x					x
7/30/19						
7/31/19	x	x	x			
8/5/19		x	x		x	
9/5/19		x	x		x	
9/12/19						
9/18/19	x					
9/25/19		x				
10/10/19	x				x	
10/23–26/19		x			x	x
11/4/19	x			x		
11/15/19						
11/22/19						
01/6/20	x	x	x	x	x	x
01/23/20		x	x	x		x
01/29/20	x			x		x
Total	13	13	11	7	9	10

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

The purpose of the steering committee was to provide guidance on the scope of the program and its deliverables and ensure that the program activities and products had the necessary support across WIDA departments. The steering committee provided input on the nature of the program (e.g., whether it should be a project within a department or an independent program), its mission and vision, and major deliverables. The committee helped ensure that the program went through all the necessary internal approval processes, even as these processes were still being designed and MSM often served as a test case. Most importantly, the steering committee approved the involvement of staff from different WIDA departments to support the activities of the program.

The co-leaders established a different infrastructure to sustain NSTA's commitment to the MSM program: Meetings between the leaders of NSTA and WIDA. The meetings took place every few months. The majority of the meetings were virtual though some also took place in person during NSTA conferences. Key participants in the meetings were the NSTA executive director and WIDA director. The meetings paved the way for the signing of the affiliation agreement between WIDA and NSTA. (The affiliation agreement formalized the collaborative relationship between the two organizations and thus made MSM possible.) The meetings also helped the co-leaders identify NSTA staff that could support key activities of the program and join the science team. The meetings created opportunities for members of the two organizations to become familiar with the ways in which each functioned, come to an understanding about the roles and responsibilities of the two organizations in supporting MSM, and negotiate thorny issues such as the intellectual property of co-developed resources.

Personal characteristics

We have already addressed the relationship of trust and mutual respect that the two MSM co-leaders cultivated (see *Interdependence*). Here, we focus on another personal characteristic that was foundational to the collaboration: The commitment to the equitable education of multilingual youth. Crowther and MacDonald shared a passion for increasing the opportunities available to multilingual youth to participate fully in the disciplinary practices of science and engage with science concepts and ideas. This shared passion created a feeling of trust and laid a strong foundation for all other discussions. The co-leaders' commitment to equity was also a source of inspiration that motivated them to do the work related to the program. According to Crowther, the relevance of the MSM to students' school experiences gave him back "his passion for education" and got him "excited about the work again" just as he was thinking about retiring (Crowther, virtual meeting, May 15, 2019). The shared commitment to equitable student engagement in science learning motivated the co-leaders to foreground equity concerns when integrating science and language learning.

History of collaboration

Our findings support Bernstein's claim that a person's history of working across fields contributes to the success of interdisciplinary collaboration. Both Crowther and MacDonald had engaged in work that bridged science and language education before the founding of MSM. Four years before MSM was established, MacDonald worked on a development grant from the National Science Foundation and created resources to support math and science teachers in engaging multilingual students in sense making (WCER, 2017). The work on the grant involved close collaboration with experts in math and science education. Crowther had also collaborated with language experts in the past. In 2006, NSTA published a volume that he co-edited, which focused on science instruction for multilingual learners (Fathman and Crowther, 2006). This history of collaboration is evidence of the co-leaders' commitment to the science education of multilingual students and helped them build knowledge about each other's fields. This knowledge in turn made it easier for the co-leaders to find common ground when they began working together.

DISCUSSION AND IMPLICATIONS

The Design Principles as a Product of Interdisciplinary Collaboration

The interdisciplinary collaboration we have explored is important to investigate for two reasons. First, the study sheds light on the range of processes that contribute to the success and sustainability of this kind of collaboration. The study illustrates the interconnections between processes at the organizational, program, and interpersonal levels. The interdependence between content and language experts motivated both WIDA and NSTA to provide support to the MSM program. The program's existence made possible the long-term collaboration among its co-leaders and the establishment of an interdisciplinary science team. The co-leaders' flexible roles, collective ownership of goals, shared decision-making, and reflection on the collaborative process sustained the collaboration at the program and interpersonal levels. This sustained collaboration was key to the robust integration of science and language learning in the resources developed by MSM. The co-leaders' shared commitment to equity for multilingual youth led them to seek the collaboration of experts on equitable science instruction and keep equity-related concerns at the center of MSM resources.

Second, the collaboration discussed here deserves scholarly exploration because it resulted in a unique resource for science educators working with multilingual youth, the Design Principles for Engaging Multilingual Learners in Three-Dimensional Science (MacDonald et al., 2020). These design principles expand the currently available principles for integrating science and language published by Lee et al. at New York University (NYU) (2019). Table 3 summarizes some of the key features of the two sets of principles.

As the table illustrates, the NYU and MSM principles have similar purposes and reflect overlapping perspectives (two of

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

Table 3: Two sets of design principles

Dimension	NYU Design Principles (Lee et al., 2019)	MSM Design Principles (MacDonald et al., 2020)
Purpose	To guide the development of instructional materials	To guide the joint development across two organizations (WIDA and NSTA) of educator resources, instructional materials, and professional learning opportunities
Development	Design-based research: analysis of SEPs and field-testing of instructional materials	Shared knowledge building: Discussions of literature on equitable science teaching as well as frameworks and position statements from national organizations in science education and language education
Perspective	1. Science and language learning go hand in hand: Students develop language as they participate in three-dimensional science teaching 2. To develop language, students need opportunities to engage in joint action and purposeful communication in science classrooms 3. Multilingual students are capable of participating meaningfully in the science learning no matter their language proficiency	1. Multilingual learners need to see their cultural backgrounds and gender identities represented in the scientists discussed in curricular materials 2. Multilingual students are capable of participating meaningfully in the science learning no matter their language proficiency 3. Science and language learning go hand in hand: Students develop language as they participate in three-dimensional science teaching 4. Feedback on students' language use needs to expand students' understanding of and effective participation in science discourses and practice
Principles	1. Science design principles: a. Multilingual students engage with phenomena and problems that involve their everyday experiences and everyday language in homes and communities b. Multilingual students engage in three-dimensional science learning, and SEPs in particular c. As multilingual students develop deeper science understanding over the course of instruction. 2. Language design principles: a. Multilingual students use multiple modalities in increasingly strategic ways b. In the course of science instruction, students move towards more specialized ways of using language. c. Multilingual learners use every day and specialized registers to make sense of science ideas.	1. Multilingual students have the right to equitable science instruction, which supports engaged civic participation and provides access to further education and STEM careers. 2. Equitable science education means that educators acknowledge historical and contemporary disparities in power and work to disrupt them. 3. Learning science creates opportunities for collaborative engagement with phenomena in ways that matter to youth, their communities, and the world. 4. Educator responsiveness to multilingual students' ideas is central to the development of students' interests and identities in science. 5. Engagement in SEPs supports collective sense making in the moment and over time, and fosters gradual shifts in language use. 6. Educators foster multilingual students' sense making in science when they position students as co-inquirers whose interests, questions, and contributions are valuable for everyone's learning. 7. Equitable science instruction leverages as assets students' experiences, ways of knowing, and cultural and linguistic resources. 8. Science instruction that leverages a broad range of language resources and multiple modalities helps students expand their repertoires of language use.

the components are the same across the two resources). The alignment in perspectives is not surprising, since both sets of principles are rooted in a sociocultural view of learning (Lee et al., 2019). This view implies that the richest opportunities for language development exist in the context of student participation in disciplinary practices and discourses, and students with a wide range of linguistic competences in English can participate in three-dimensional science learning (Lee et al., 2013).

The unique contribution of the MSM design principles becomes visible through a comparison of the actual principles. As the "principles" row in Table 3 showcases, the NYU principles are divided into science and language design principles. The MSM design principles, on the other hand, represent a coming together of equity, language development, and science learning priorities, and constitute a set of principles in which language and science considerations cannot be disentangled from one another. This robust integration was made possible through the rigorous and sustained process of interdisciplinary collaboration that led to the development of the MSM principles.

The tighter integration of science and language in the MSM principles has important implications for science instruction. One example is the approach to SEPs. Lee et al. (2019) position SEPs as the key to multilingual students' equitable participation in science learning. The authors identify some SEPs as "language-intensive" (Lee et al., 2019, p. 319), which suggests that students' engagement in these practices makes language scaffolding particularly necessary. The MSM principles, on the other hand, do not highlight any elements of science instruction as being more language-intensive than others. Instead, the MSM principles foreground the importance of student participation not only in SEPs but also in disciplinary discourses. This approach shifts educators' attention from the necessarily subjective assessments of the language intensity of certain activities to students' participation in sense making. MacDonald et al. (2020) refer to principles 3-6 in Table 2 as the "four pillars for sense-making in science instruction" (p. 4).

Another implication of the deep integration of science, language, and equity in the MSM design principles is the emphasis on power and student agency. Principle 2, for

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

example, directly addresses issues of power inherent in science education and calls on educators to disrupt inequitable educational practices that limit multilingual students' access to rigorous science learning. Principle 6 underscores the importance of promoting student agency and positioning students as co-inquirers. These principles (among others) expand the language-focused recommendations in Lee et al. (2019) by addressing not only students' language use but the patterns of participation to which students have access in science classrooms. This critical approach acknowledges that oppressive educational structures cannot be counteracted solely by supporting multilingual students' language development; equitable instruction for multilingual youth requires shifts in awareness and the social positioning of multilingual students (Flores and Rosa, 2015).

CONCLUSION

The study explored the processes and products of interdisciplinary collaboration with an emphasis on the science education of multilingual youth. The findings showcase what it takes to integrate equity, content, and language in resources designed to inform content-area instruction for multilingual learners. The research focused on the unique context of interorganizational collaboration and sheds light on organizational, program, and interpersonal factors that shape this collaboration. Since it was a case study, the findings of the research are not generalizable to other contexts. Along with other studies, however, the analysis can contribute to the knowledge base of what makes interdisciplinary collaboration effective. It is our hope that the study can inform the efforts of scholars and educators who are particularly interested in supporting the academic success of multilingual youth.

REFERENCES

Allen, M. (2017). *The SAGE Encyclopedia of Communication Research Methods*. SAGE.

Bouwma-Gearhart, J., Perry, K.H., & Presley, J.B. (2014). Improving postsecondary STEM education: Strategies for successful interdisciplinary collaborations and brokering engagement with education research and theory. *Journal of College Science Teaching*, *44*(1), 40-47.

Bronstein, L. (2003). A model for interdisciplinary collaboration. *Social Work*, *48*(3), 297-306.

Bybee, R., Taylor, J.A., Gardner, A., van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications*. Biological Sciences Curriculum Study.

Callahan, R., & Shifrer, D. (2016). Equitable access for secondary English learner students: Course taking as evidence of EL program effectiveness. *Educational Administration Quarterly*, *52*(3), 463-496.

Cheng, X., Pan, W., & Zhang, Q. (2019). Antecedents of knowledge interaction in the sustainable interdisciplinary research team: A mixed research method. *Sustainability*, *11*, 1-23.

Fathman, A., & Crowther, D. (2006). *Science for English Language Learners: K-12 Strategies*. National Science Teaching Association.

Flores, N., & Rosa, J. (2015). Undoing appropriateness: Raciolinguistic ideologies and language diversity in education. *Harvard Educational Review*, *85*(2), 149-171.

Gibbs, G. (2007). *Analyzing Qualitative Data*. SAGE.

Gunawardena, S., Weber, R., & Agosto, D.E. (2010). Finding that special someone: Interdisciplinary collaboration in an academic context. *Journal of Education for Library and Information Science*, *51*(4), 210-221.

Johnson, K.F., Belcher, T.W., Zimmerman, B., & Franklin, J. (2020). Interprofessional partnerships involving school counsellors for children with special needs: A broad based systematic review using the PRISMA framework. *Support for Learning*, *35*(1), 43-67.

Khoo, S.M., Haapakoski, J., Hellsten, M., & Malone, J. (2019). Moving from interdisciplinary research to transdisciplinary educational ethics: Bridging epistemological differences in researching higher education internationalizations. *European Educational Research Journal*, *18*(2), 181-199.

Klaassen, R. (2018). Interdisciplinary education: A case study. *European Journal of Engineering Education*, *43*(6), 842-859.

Lee, O. (2019). Aligning English language proficiency standards with content standards: Shared opportunity and responsibility across English learner education and content areas. *Educational Researcher*, *49*(6), 426-432.

Lee, O., Llosa, L., Grapin, S., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education*, *103*(2), 317-337.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to next generation science standards and with implications for common core state standards for English language arts and mathematics. *Educational Researcher*, *42*(4), 223-233.

Löfström, M. (2010). Inter-organizational collaboration projects in the public sector: A balance between integration and demarcation. *International Journal of Health Planning and Management*, *25*, 136-155.

MacDonald, R., Crowther, D., Braaten, M., Binder, W., Chien, J., Dassler, T., Shelton, T., & Wilfrid, J. (2020). *Design Principles for Engaging Multilingual Learners in Three-Dimensional Science. WCER Working Paper No. 2020-1*. Wisconsin Center for Education Research. Available from: https://www.wcer.wisc.edu/publications/working-papers.

McNeill, K., & Martin, D., (2011). Claims, evidence, and reasoning: Demystifying data during a unit on simple machines. *Science and Children*, *48*(8), 52-56.

Molle, D., & Huang, W. (2020). *Making Science Multilingual: An Interdisciplinary Program and its Evolution (WIDA Research Report RR-2020-1)*. Madison: WIDA. Available from: https://wida.wisc.edu/sites/default/files/resource/Making-Science-Multilingual-Report.pdf.

Moore, E., Ploettner, J., & Deal, M. (2015). Exploring professional collaboration at the boundary between content and language teaching from a CHAT approach. *Ibérica*, *30*, 85-103.

National Academies of Sciences, Engineering, and Medicine. (2018). *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives*. The National Academies Press.

Neill, C., Corder, D., Wikitera, K.A., & Cox, S. (2017). Embracing the muddle: Learning from the experiences from interdisciplinary teaching and learning collaboration. *New Zealand Journal of Teachers Work*, *14*(2), 136-154.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, by States*. The National Academies Press. Available from: https://www.nextgenscience.org/standards/standards.

NSTA. (2020). *About NSTA*. Available from: https://www.nsta.org/overview.

Palladino, J. (2011). Who's who and what's what? Special education services for foster care students. *Journal of Cases in Educational Leadership*, *14*(1), 13-24.

Retrouvey, H., Zhong, T., Gagliardi, A.R., Baxter, N., & Webster, F. (2020). How ineffective interprofessional collaboration affects delivery of breast reconstruction to breast cancer patients: A qualitative study. *Annals of Surgical Oncology*, *27*, 2299-2310.

Summers, R., Rodems, K., Denos, S., & Atkinson, A. (2019). Using claims and evidence to support the search for extraterrestrial life: Teacher reflections following an interdisciplinary English-science argumentation unit. *Middle School Journal*, *50*(2), 5-16.

Tiongson, M. T. (2018). Interdisciplinary teacher collaboration for English for Specific Purposes in the Philippines. *University of Sydney Papers in TESOL*, *13*, 29-62.

Tinnell, T., Tretter, T., Thornburg, W., & Ralston, P. (2019). Successful

Science Education International
32(2), 114-124
https://doi.org/10.33828/sei.v32.i2.4

interdisciplinary collaboration: Supporting science teachers with a systematic, ongoing, intentional collaboration between university engineering and science teacher education faculty. *Journal of Science Teacher Education*, *30*(6), 621-638.

Vanasupa, L., McCormick, K.E., Stefanco, C.J., Herter, R.J., & McDonald, M. (2012). Challenges in transdisciplinary, integrated projects: Reflections on the case of faculty members' failure to collaborate. *Innovative Higher Education*, *37*(3), 171-184.

Wannenmacher, D. (2020). Obstacles and levers of interdisciplinary collaborative work. The case of ALLIBEAS. *Knowledge Management Research & Practice*, *18*(1), 110-119.

WIDA. (2020). *Mission and History.* Available from: https://www.wida.wisc.edu/about/mission-history.

Wisconsin Center for Education Research. (2017). *Doing and Talking Math and Science: Strengthening Reasoning, Strengthening Language.* Available from: http://stem4els.wceruw.org/index.html.