LINGUISTIC TENSIONS IN GENERALIZING A MATHEMATICS EDUCATION FRAMEWORK FOR STEM EDUCATION

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Research processes are often messy and include tensions that are unnamed in the final products. In our attempt to update and generalize a framework used to examine teachers' support for collective argumentation in mathematics education classrooms to examining teachers' work in interdisciplinary STEM contexts, we have experienced significant linguistic tensions because of the context-dependent nature of language. We aim to acknowledge the difficulty of generalizing research beyond the mathematics education community, describe our attempts to resolve the problem we face, and discuss potential conclusions pertaining to the feasibility of generalizing frameworks beyond mathematics education.

Keywords: Classroom Discourse; Integrated STEM/STEAM; Research Methods

Background

In 2019, Eric Siy asked the mathematics education community to reveal their work to cultivate a healthier and more rigorous culture of research. Siy argued that one way to expose the messiness of research was to make our processes products. In response to his call, our team has decided to openly share a present, messy tension in our research process. By disclosing our present dilemma to the community for outside opinion and critique, we aim to practice academic humility and make our process a product.

The current tension emerged out of our attempt to update and extend the Teacher Support for Collective Argumentation (TSCA) framework (Conner et al., 2014) that was originally developed to understand and describe how secondary mathematics teachers support collective argumentation. We define collective argumentation as teachers and students working together to establish a claim and provide evidence to support it. The original framework described teachers' support of collective argumentation as (a) directly providing a claim, data, or a warrant, (b) prompting a student's contribution of argument components with a question, or (c) responding to a student's contribution. These three descriptions of teacher support for collective argumentation simplify to three categories: direct contributions, questions, and other supportive actions.

Given the utility of the original framework, we (a group of mathematics education, science education, and engineering education researchers) attempted to update and extend the framework to other STEM+C settings/classrooms. Our updates include specific kinds of questions within each broader category of question. For example, Table 1 shows a few of the kinds of questions originally conceptualized. In the updated framework, we want to potentially include additional kinds of questions as well as examples from multiple disciplines.

Table 1: Working Descriptions of Selected Types of Questions in New TSCA Framework

Category of Question	Description
Requesting a factual answer: Asks students to provide a mathematical fact	*Identification*: choose from a set of options, identify something *Observation*: describe what happened or is happening.
Requesting a method: Asks students to demonstrate or describe how they did something	*Describe a method*: state how they did, would, or could do something
Requesting an idea: Asks students to compare, coordinate, or generate mathematical ideas	*Conjecture*: put forward a prediction, suggestion, or other idea

Note. This table is adapted from the original TSCA framework (Conner et al., 2014, p. 419)

However, in our attempt to update and generalize the framework for use in other contexts, we experienced significant linguistic tensions. The complexity of meaning and the context-dependent nature of language pose severe challenges for crafting the framework for use beyond mathematics education. In this brief research report, we aim to acknowledge the difficulty of generalizing research beyond the mathematics education community, describe our attempts to resolve the problem we face, and discuss potential conclusions pertaining to the feasibility of generalizing frameworks beyond mathematics education.

Theoretical Framework

Ludwig Wittgenstein, in his *Philosophical Investigations* (1953/1958), sought to dismantle theories of language that were referential, representational, and ostensive at their core. A referential view of language is where words directly refer to objects and, consequently, a word has a referential meaning. Wittgenstein wanted readers to break free from the idea that there could be a unitary account of language (Grayling, 1988). Rather than an all-encompassing theory, Wittgenstein proposed the concept of language-games. Wittgenstein's concept of language-game was meant to emphasize that language is not independent from context nor is it referencing some outer reality. Rather, Wittgenstein (1953/1958) described language-games as "meant to bring into prominence the fact that the speaking of language is part of an activity, or of a form of life" (§23). Grayling (1988), expounding on Wittgenstein's phrase "form of life," wrote,

> Language is not something complete and autonomous which can be investigated independently of other considerations, for language is woven into all human activities and behaviour, and accordingly our many different uses of it are given content and significance by our practical affairs, our work, our dealings with one another and with the world we inhabit—a language, in short, is part of the fabric of an inclusive 'form of life.' (p. 67)

Through his exploration of concepts like "language-games" and "form of life," Wittgenstein sought to reinforce his main point: the meaning of language is largely found in its *use* in humans' embodied activities and social practices (i.e., in various language-games). Hence Wittgenstein wrote, "the meaning of a word is its use in the language" (§43). Given Wittgenstein's ideas about language and meaning, we should not be surprised that the same word is used across various

STEM+C disciplines with different meanings. Furthermore, a word's meaning may not be easily disentangled from its disciplinary use and the associated embodied practices and contexts.

Methods

The data for the larger project consist of many hours of video from elementary teachers' instruction in which they integrated coding with mathematics, science, literacy, and social studies lessons. To examine the teachers' use of argumentation and support of students' arguments across disciplines, episodes of argumentation were identified, verbatim transcripts were prepared, diagrams of arguments were constructed, and teachers' actions supporting the argumentation were identified according to the methods described in Conner et al. (2014).

Our research team met for multiple hours each week to analyze and discuss our coding of teachers' supportive actions with respect to the original framework. In the summer of 2021, a member of the research team highlighted a prominent linguistic tension about the use of codes within two categories (requesting a method and requesting an idea) in the framework. Subsequently, the use of two additional words was identified as problematic. Our team regularly debated how to use the framework in light of these tensions for the subsequent months. Multiple times, we attempted to settle the debate and move forward by adopting specific meanings for the words. However, further analysis caused additional complications of meanings, and more linguistic tensions were identified. In the most recent attempt to settle various meanings, all team members were asked to submit their own working definition of four contentious terms and to describe the types of practices and activities that are associated with the words within their home discipline.

Results

Table 2 shows four debated words and their meanings (derived from combining provided definitions) within each field. Each of these words was used as a kind of question in the evolving TSCA framework.

Table 2: The Meaning of Words in Different Fields

	Science	Engineering	Mathematics	Statistics
Conjecture	Guess, prediction, or tentative solution; cannot be positively justified; distinct from hypothesis	Idea or hypothesis that is tested out	Prediction, reasoned guess, or proposal of a method for a problem [a]; do not have a proof	Alternative hypothesis or claim related to a research question
Method	Systematic approach to answering a question; process or technique used to find a solution to a problem [a]	Process or technique to transform an idea into a physical reality	Abstract sequence of actions or steps used to solve a problem [a], prove something, or achieve something	Technique to collect data; statistical investigative cycle; statistical approach to solving a problem[a]
Identification	Categorizing or classifying an object into pre-	Pointing out attributes that define	Determine/select what thing (object, drawing, etc.) has a	Not applicable

	established categories based on observable characteristics	something such as a design problem[a] or a design solution	certain characteristic	
Observation	Method of data collection through one's senses and scientific tools; necessarily an interpretation in light of a theory	Assembling facts from what one can see or notice	Statement noting something's (object, drawing, etc.) characteristics	A single measurement of a variable; recognizing trends or patterns in data or a graph

[a] The word "problem" provides another layer of difficulty; the types of problems imagined by scientists, engineers, mathematicians, and statisticians are different.

Discussion and Continuing Dilemmas

Given these words have loaded meanings that are discipline-dependent, our team identified three potential options. First, we could concede and conclude that there is no opportunity to generalize this framework across disciplines—even in related STEM disciplines. Second, we could carefully choose words that are not loaded with meaning in multiple disciplines. This option poses two difficulties: (a) words that do not have discipline-related meanings can often have colloquial meanings and (b) by attempting to avoid discipline-related meanings, we may choose a watered-down word that does not sufficiently communicate the type of question the teacher used. Finally, we could use the words that we currently have in the framework and accept that they will cause friction for some of the disciplines.

As we explored these three options, our team was pushed to re-examine the original purposes of the project. Given our aim of helping STEM teachers support collective argumentation, we believe it is worth attempting to generalize the TSCA framework, and if possible, to use words that would be understandable across disciplines. In our attempt to pursue the second option, we concluded that, by replacing the word "Observation" with the word "Description," we could communicate our intended meaning and avoid discipline-specific meanings. However, we have not come to a consensus on "Conjecture," "Method," and "Identification."

This constructive work across disciplines required researchers to adapt and adopt new meanings for words—meanings that can cause friction with the discipline-specific meanings. Addressing this dilemma has required group members to intentionally learn more about the meanings and uses of words across disciplines, highlighting the epistemic and linguistic differences between related disciplines. This calls into question the ease with which teachers can engage in integrative STEM instruction and suggests the need for intentionality in building theory across disciplines.

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