Fostering Educator Buy-in of Language and Literacy in the Science Classroom

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Abstract: This paper describes a project to build linguistic awareness among science educators at multiple levels: pre-service K–12 teachers, in-service K–12 teachers, and university faculty in both education and STEM fields. Educational linguists from a language-focused non-profit research organization created modules on teaching culturally and linguistically diverse students for a Master of Arts in Teaching (MAT) program for middle school science educators at a large urban U.S. university. The module content, which was integrated into three science education methods courses, was designed around three key principles: linguistic understanding, critical language awareness, and pedagogical modeling. A critical component to the project’s success was fostering “buy-in” from the various groups of educators through multiple means, including piloting materials with in-service science teachers, training university faculty on the language and literacy materials, and revising content based on feedback from the MAT program faculty and students. The findings demonstrate that over time, the educators re-examined their roles as teachers of language and literacy and reassessed their thinking related to science instruction, highlighting the efficacy of incorporating language development content into training and professional development for STEM educators at multiple levels.

Keywords: STEM education; professional development; content and language/literacy integration; multilingual learners; content-rich instruction; cultural and linguistic diversity; language-rich classrooms; equity-focused pedagogies

1. Introduction

With the increasing diversity of U.S. school populations, rigorous college and career readiness standards, and language and literacy demands inherent in all grade-level content topics and tasks, educators need to feel confident and knowledgeable about language, both as users and teachers of language [1,2]. Many secondary teachers enter the profession to focus on their discipline, expecting students to arrive with the requisite language and literacy skills and with little formal training on how to help students read, write, and converse within content area classrooms [3]. With the assumptions that scientific principles and phenomena are universal and that lab activities involve observation and action-oriented activities, science teachers often ignore that language is embedded in each facet of the Science, Technology, Engineering, and Mathematics (STEM) classroom, such as listening to directions, reading procedures, discussing observations, and writing up findings. While all students can benefit from explicit attention to language within content instruction, scaffolds to support language development and access to grade-level content are particularly important for culturally and linguistically diverse (CLD) learners, benefitting not only their content mastery but also their identity development [4,5]. In this project, CLD students includes multilingual learners as well as students whose first language is English but who speak varieties of English based on their region, ethnicity, race, or other background factors.
This article describes the development of a Master of Arts in Teaching (MAT) program at an urban, historically Black university initiating a new STEM concentration. The MAT program had several overarching goals, including increasing the number of women and under-represented minorities in STEM areas and addressing the need for more effective approaches to STEM education among students who are diverse in their culture, language, or learning abilities and preferences. Thus, while the MAT program was initiated over 10 years ago, it was designed to support groups that have historically been impacted by systemic racism and aligns with more recent equity and social justice-oriented work in the field [6]. Most of the program’s leadership, including the principal investigator, co-investigator, and several program faculty, identified as Black, as did the MAT candidates (“teaching fellows”).

One component of the program focused on infusing language education within the STEM concentration so that the teaching fellows would be better prepared to support CLD students in their classrooms. The effort was led by educational linguists from a language-focused non-profit research organization who identified the core components of the STEM language education program and developed course materials that would be used by science education faculty in the MAT courses. This project aimed to address educators’ gaps in knowledge and pedagogical resources by building a foundation in understanding the components of language in science classrooms; acknowledging the diversity of language usage and users within the classroom; and learning how to teach language while simultaneously developing students’ conceptual understanding and identity development. In order to succeed, the educational linguists also needed to earn educator buy-in on the significance of language in their classrooms and the idea that teaching language would help their students, particularly CLD students, learn scientific concepts and develop their abilities to communicate in STEM subjects. It is important to note that the educational linguists are White, with English-speaking linguistic privilege. Thus, while the educational linguists served as language experts, the process of developing the language content was collaborative across all stakeholders, which follows recommendations of recent movements such as liberatory linguistics [7] that promote linguistic justice in higher education settings. In this article, we describe the program’s core language components, how they were identified and infused into the program, how course materials were piloted with three groups of educators, and finally, how the materials were received and revised once implemented in the MAT program.

1.1. CLD Students in U.S. Classrooms and STEM Fields

Diversity in U.S. classrooms has grown at an unprecedented rate in the past decade [8,9]. For example, the percentage of non-White students in U.S. public schools has increased significantly from 48% in 2010 to an estimated 54% in 2020. The increasing diversity among U.S. students is not, however, reflected in the demographics of classroom teachers, as the vast majority of K-12 teachers are White, monolingual, middle-class women. According to the NCES, while 51% of U.S. public school students were ethnic and racial minorities during the 2015–2016 school year, only 20% of teachers were non-White [8,9]. Despite this demographic mismatch, research has further shown that the needs of CLD students are frequently overlooked in teacher education programs, and that teachers report feeling unprepared to meet their CLD students’ needs, particularly in the implementation of rigorous content area standards [10,11]. These gaps extend to teachers’ knowledge of language use and instruction within content areas [1]. Closing such gaps is critical, as research has shown that language learning is facilitated when teachers are open to linguistic and cultural diversity in their classrooms and communities [12,13].

Compounding these issues are beliefs and ideologies surrounding “standard” language, or the perception that a variety of English exists that is superior to others [14]. The belief in a standard variety of English has resulted in a pervasive deficit-oriented view of many dialects of English, including African American Language (AAL), that has in turn led to language-focused debates within the field of education. These debates and
misunderstandings about language within the field of education highlight the critical need for teacher education that not only incorporates but emphasizes linguistic diversity and inclusion [15]. Moreover, a prescriptive focus on linguistic form, rather than integrating language and content instruction with an emphasis on meaning, is a missed opportunity to support not only language and identity development but also the comprehension of content for all students [16].

Furthermore, the National Science Foundation identifies several groups as under-represented in STEM careers and advanced degrees: women, Hispanics or Latinos, Blacks or African Americans, American Indians or Alaska Natives, and Persons with Disabilities. Even with college degrees in STEM fields, these groups are less likely to be employed in science and engineering jobs after graduating and attain lower median salaries than their White counterparts [17]. To address the under-representation of minorities in STEM fields, the overall goals of the new MAT program were to increase the number of CLD K-12 STEM teachers, raise the profile of minorities in STEM, and inspire CLD students to enter STEM fields. At the same time, the educational linguists' main purpose was to prepare teachers to work with CLD students and to help them reflect on and perhaps dismantle their own beliefs related to standard language and English-only education.

1.2. Collaboration with Three Groups of Educators: Eliciting Educator Buy-in

Educator buy-in, including from administrators and teaching staff, is fundamental to a successful intervention, school reform, or professional development (PD) program. Educator buy-in is a willingness to learn about an initiative or topic and an expectation that the information or strategies will be beneficial, leading to a change in the instructional practice or attitudes. To achieve fidelity in implementing school interventions, it is critical to include all educational stakeholders in planning and decision making [18]. Furthermore, both changes in attitudes and in instructional practice are significant in measuring educator buy-in. According to Macy and Wheeler [19], barriers to professional buy-in include a lack of consistency of program implementation, lack of administrative support, and lack of time. On the other hand, incentives like professional credits, stipends, or early leave have been associated with higher rates of buy-in.

The quality of PD further impacts teacher buy-in. Teachers frequently express greater interest in content that can be immediately applied, like learning a classroom strategy. However, recent research has favored more long-term, sustainable PD that impacts teachers’ knowledge and practices, with the ultimate goal of improving student outcomes, as opposed to “one-and-done” workshops [20,21]. Other identified components of effective PD include the following: a content focus, active learning through adult learning theory, collaboration with colleagues, models of effective practice, coaching and expert support, opportunities for feedback and reflection, and longer-term duration [20,22]. Given the gaps in teacher preparation discussed previously, most educators, including teacher educators, have had little exposure to the principles of linguistics or pedagogical tools needed to meet the needs of CLD learners [23,24]. Indeed, prior studies have shown that teacher educators with a higher understanding of language constructs produce teacher candidates with a higher understanding of these constructs [23], highlighting the need to include teaching faculty as part of pre-service interventions.

2. Materials and Methods

2.1. Program Description

This project is part of a larger initiative to create a transition-to-teaching program for professionals in STEM fields who were under-represented minorities and interested in transitioning to middle school science education positions. These teaching fellows participated in a 20-week Practice of Science internship; a Master’s degree that emphasized foundations of urban education, content area pedagogy, and field experiences; and three years of new teacher mentoring after graduation. As the teaching fellows were placed in high-need K-12 school districts, the MAT program intentionally integrated content on the academic
language of science and differential instruction for CLD learners into the curriculum. While there are many views on the construct of ‘academic language’, project staff adopted the position that the teaching fellows needed to be aware of various perspectives and have the opportunity to critically reflect on them as part of their coursework [16]. Using this approach, the educational linguists created modules for face-to-face and online class sessions that were integrated into the MAT curriculum.

To develop the content for the program, the educational linguists engaged in regular meetings with the MAT program leadership. As part of the planning process, the MAT program leadership asked the educational linguists to review the assessments that the teaching fellows would need to pass for licensure. The linguists reviewed these assessments and identified the specific language development skills that the teaching fellows would need to develop during their MAT program. Two assessments in particular tested language-based skills: the edTPA and the lesson and unit plan.

The edTPA is a multiple measure assessment of teaching. Within the assessment system, academic language is treated as a central component. Furthermore, in each content area, academic language is specifically addressed as central to learning. EdTPA defines academic language as the language of the school, content, and classrooms. It is the language that students need in order to understand, communicate, and perform in the content disciplines. Academic language includes the oral and written language structures used in the content area, the “thinking” structures used to organize and connect complex ideas, and the meaning-making strategies used to understand and communicate [25].

The edTPA states that it expects teacher candidates to be able to attend to the vocabulary, syntax (sentence-level features), and discourse that students will need to learn to participate in content. Teacher candidates are expected to have the ability to scaffold students’ academic language development, taking into account students’ current academic language abilities and what they need to do in order to develop more advanced skills. Thus, the teaching fellows would need to understand the specific ways in which academic language manifests in science and attend to academic language when planning for and teaching lessons, incorporating appropriate activities to develop academic language while simultaneously engaging in disciplinary (i.e., scientific) practices. This perspective of academic language is somewhat traditional and form-based, focusing on linguistic features of this valued form of discourse. However, it does not account for the ways in which CLD students engage with this discourse to reflect their positionality to it. Nonetheless, this perspective of academic language was reflected in course materials, because it was the perspective of a powerful gatekeeper in the credentialing process that the teaching fellows needed to be aware of [4,5].

The unit and lesson plan format used by the MAT program was adapted from Morgan State University. It provided the option of examining language at different levels of linguistic generality, including word, sentence, and discourse levels. Other components included identifying students’ existing academic language abilities, supports to scaffold students’ academic language development, and ways of assessing students’ academic language development during a learning segment. After reviewing the knowledge and skills that would be expected of the teaching fellows, the linguists outlined the components of the modules, which were then reviewed by the MAT program leadership. The leadership provided guidance on how the modules would be integrated into the MAT program; initially, the modules were developed to fit into the two methods courses of the STEM concentration.

2.2. Core Linguistic Components

The modules focused on three core components: understanding the language of science, critical language awareness (CLA), and pedagogical modeling. The first core component of the project materials was increasing the teaching fellows’ understanding of the language of science, which is rooted in three foundational principles:
The first foundational principle is the intrinsic value of all students’ existing styles of language use and home language as resources. Scientific language does not necessarily align with everyday ways of using language, making it challenging for all students [4,5,26–29]. Research on CLD students’ scientific discourse has shown that they can engage in productive scientific discourse when they are taught in ways that value and take their linguistic resources into account [30,31]. However, some students may choose not to use science discourse, because it is not congruent with their identities [4,5]. Thus, a key principle was to foster the understanding that all students’ ways of using language should be valued, understood, and leveraged in the classroom in support of learning.

A second foundational principle is that teachers and students need to understand the role of language within science as a discipline and in science classroom contexts [32]. By supporting the teaching fellows’ awareness of the features of the language of science, they would be in a better position to scaffold their students’ development of it.

The third foundational principle is that students’ language skills should be developed in tandem with their conceptual understanding of science ideas. School science affords opportunities to learn and use language to engage in science learning [33–36]. Science classrooms provide opportunities for students to engage in different kinds of scientific discourse that may be uncommon in their everyday lives. Language is part and parcel of learning science; it may be difficult for students to express a conceptual understanding without having the language to express it. From this perspective, language learning need not be a separate activity in the science classroom, or outside of the science classroom. Rather, students’ attention should be drawn to the language of science and the ways in which it is used in the moments of learning science.

The second component of the materials was critical language awareness (CLA). Fairclough [37] defines CLA as “how language conventions and language practices are invested with power relations and ideological processes which people are often unaware of” (p. 7). Throughout the materials, language was not viewed only from a form-based perspective, which is common of many approaches to academic language. On the contrary, language was treated as a way to make meaning in a social context. Thus, as the teaching fellows became more aware of linguistic form, they were asked to critically reflect on their own opinions about language in academic settings. Alfouain [38] writes, “[language] educators who are armed with CLA knowledge are capable to change the conventional ideology that proposes the superiority of one language over another for any reason”. Because language is so central to classroom learning, it was important for teaching fellows to critically reflect on the role it plays in teaching and learning. The activities were designed to ask them to think about the ways in which language(s) is (are) used in different settings, how meaning is created with language(s), and what ideologies are associated with language use. The goal was for teaching fellows to develop an understanding of the ways language is used in real settings and the implicit values associated with these uses. Furthermore, the hope was that through coming to an understanding of actual language use, they would be able to better support students’ language development, valuing vernacular ways of using language and leveraging them to build students’ academic identities.

The third core component was pedagogical modeling. The modules were designed to model pedagogical approaches for teaching CLD students. Strategies and best instructional practices were embedded into module activities so that teaching fellows could experience firsthand the types of activities that could be appropriate for teaching CLD students. Each learning session was intended to model a different type of pedagogical activity aimed at promoting academic language development. In order to achieve buy-in with members of the MAT science instructional faculty and secondary science teachers, the educational linguists grounded the modules and classroom examples in grade-level science content and in alignment with inquiry-based methods of science instruction. While identifying the language demands in grade-level science within each sub-discipline (e.g., chemistry, physi-
cal science, and biology), examples were drawn from middle school classroom activities, readings, and assignments.

Module 1 was developed as six hours of instruction broken into three learning sessions, introducing teaching fellows to the construct of the academic language of science. These learning sessions were incorporated into three face-to-face class sessions in a course on the Practice of Science. The teaching fellows spent time examining the language used in science settings (both classroom and professional), analyzing examples according to word, sentence, and discourse features. To bring in the CLA perspective, naturalistic language was used; the teachers analyzed transcripts from journal articles as well as transcripts of their own language that they produced. Through personal field work in science settings, the fellows had the opportunity to observe language practices of scientists and reflect on their own personal experiences as learners. For instance, one module activity involved small group conversations around a sampling of illustrations or diagrams related to grade-level topics, such as the periodic table of elements, the rock cycle, and simple machines. The teachers discussed the content and what kind of language was necessary to discuss the scientific concepts.

Module 2 was also developed as six hours of instruction, originally broken into four learning sessions. The content from Module 2 was eventually integrated into seven class sessions across two courses, one on teaching methods in Physical, Earth, and Space Sciences and one on teaching methods in Life, Earth Science, and Chemistry. The sessions focused on teaching CLD learners in specific science content areas (i.e., life science, chemistry, earth science, and physical science) along with specific aspects of academic language development in those content areas. The teaching fellows identified specific types of language demands, looking closely at literacy demands (reading and writing) and oracy demands (listening and speaking) in science settings. They also learned how to plan instruction, focusing on language functions, language tasks, and language demands. The teaching fellows learned ways to support CLD students’ academic language development using graphic organizers and other tools. They also learned appropriate ways of formatively assessing students’ academic language development. CLA was woven throughout the modules through utilizing naturalistic examples and asking teachers to recognize their own biases related to language use.

Table 1 outlines how the core components of each module were designed and the specific topics for each of the learning sessions. For a full description of the creation and content in the module materials, including the sample activities and assignments, see Renn and Duguay (2019) [39].

Each module lesson had learning objectives, assigned readings, an activity that modeled a strategy that could be used in a middle grade science classroom, a wrap-up activity that included reviewing the objectives, and a short formative assessment, or “ticket out”. All lesson activities were anchored in the learning objectives. For example, in Module 1, Session 1, the learning objectives included the following:

- To review and discuss information about the types of language customarily used by scientists and their meaning-making potentialities;
- To problematize typical views of scientific language;
- To critically think about scientific language practices and implications for pedagogy and student learning.
### Table 1. Module materials related to the core linguistic components.

<table>
<thead>
<tr>
<th>Module</th>
<th>Learning Session</th>
<th>Understanding the Language of Science</th>
<th>Critical Language Awareness</th>
<th>Pedagogical Modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Pedagogical language knowledge and academic language of science</td>
<td>Conversations in a university physics laboratory; analysis of conversations among scientists in a lab setting</td>
<td>Transcript analysis of the living language of science; self-recording at field site and reflection paper on the contrast between naturalistic language and the language of scientific journals</td>
<td>Interviews: using guiding questions, interviews between teaching fellows about their language experiences at their field sites; this activity modeled academic conversations</td>
<td>Traveling jigsaw: teaching fellows created posters and engaged in conversations; after making the poster, groups divided and presented to members of other groups; this activity modeled informational presentations and interaction</td>
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<tr>
<td>2: Linguistic aspects of the language of science</td>
<td>Differing perspectives on academic language in school settings and how academic language applies to science settings</td>
<td>Reflection on a complex science text and the ways meaning is expressed; discussion of quotes from academic language articles and implications for teaching</td>
<td>Review of scientific language from texts and other materials to reflect different styles of scientific language use for different audiences; reflection on personal opinions about language styles (formal vs. informal, technical vs. every day, and detached vs. involved)</td>
<td>Extended anticipation guide: teaching fellows recorded initial ideas/opinions about scientific language use in classrooms; after discussion in the class, they revisited initial answers and wrote justifications; this activity modeled academic writing and argumentation</td>
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<tr>
<td>3: The academic language of science</td>
<td>Language style in and out of science classrooms</td>
<td>Analysis of middle school science texts from a genre perspective and how to help students understand them based on their linguistic backgrounds</td>
<td>Expository text frame: this activity modeled how teachers could scaffold reading and writing for CLD students; teaching fellows used authentic science texts to develop their own expository text frame</td>
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<tr>
<td>2: Strategies for supporting reading and writing in science classrooms</td>
<td>Genres of writing in science contexts</td>
<td>Principles of effective instruction for CLD learners; language objectives; strategies to target reading and writing in science instruction</td>
<td>Reflection on reading and writing practices in science instruction; lesson plan incorporating reading and writing in science instruction</td>
<td>Sentence generation, round robin writing, interactive reading, and snowballs: after each activity, teaching fellows considered how the activity met the principles of effective instruction for CLD students and how they would adapt the activity in their classroom</td>
</tr>
<tr>
<td>1: Reading and writing in science classrooms</td>
<td>“Speech events”, science talks, and a case study from NGSS; transcripts from a middle school classroom</td>
<td>“Speech events”, science talks, and a case study from NGSS; transcripts from a middle school classroom</td>
<td>Reflection on examples of scientific language from classroom transcripts and personal opinions about language styles including biases</td>
<td>Talking chips: teaching fellows reviewed content material in a small group and became mindful of turn-taking strategies in interactive speaking and listening</td>
</tr>
<tr>
<td>4: Strategies for supporting speaking and listening in science classrooms</td>
<td>Principles of effective instruction for CLD learners; language objectives; strategies to target speaking and listening in science instruction</td>
<td>Principles of effective instruction for CLD learners; language objectives; strategies to target speaking and listening in science instruction</td>
<td>Reflection on speaking and listening practices in science classrooms; lesson plan incorporating speaking and listening skills in science instruction</td>
<td>Inside/outside circles, fan and pick, dictogloss, video observation guide, mental paragraphs, and information gaps: after each activity, teaching fellows considered how the activity met the principles of effective instruction for CLD students and how they would adapt the activity in their classroom</td>
</tr>
</tbody>
</table>

Many of the activities were developed for teaching fellows to engage with the concepts in their assigned readings. For example, prior to reading an article by Gee [40], the teaching
fellows completed an anticipation guide, which is a reading comprehension activity. The participants read a list of statements or viewpoints related to the text before reading, indicating their agreement with the statements. After reading the text, the participants returned to the anticipation guide; in a new column, they indicated their agreement with the same statements. Finally, they explained why their answers may or may not have changed based on the reading. For the Gee article, sample statements included “conversational styles are developed by adolescence” and “some students may see the identity of a scientist and the ways of using language in science as conflicting with their other identities” [40]. The statements are meant to promote discussion and critical thinking for students, as well as a close reading of text.

Another example that modeled a middle grade classroom strategy while allowing teaching fellows to engage with graduate-level content was a talking chips activity [41]. In this activity, teachers examined the power dynamics of language by discussing various quotes. Each participant is given a limited number of small tokens (e.g., paperclips) to control the discussion before a free-flowing conversation can occur. In this lesson, the teaching fellows were asked to react to quotes from the text and/or an accompanying question. For each quote, the participants surrendered a talking chip into the center of the table each time they participated in the discussion. An example quote by van Lier and Walqui [42] is “It is argued that the multilingual reality of the world is not adequately served by a monolingual ideology that assumes the existence of a ‘native speaker’ whose perfections all learners should strive to attain. The very idea of linguistic purity is brought into question”.

“Tickets out” were designed to model a formative assessment that could be used to evaluate middle school students’ learning after a lesson: literally a ticket to leave the classroom. The professor posted pre-planned prompts, asking teaching fellows to, for example, name three takeaways from the class, ask questions about the content, or describe how they might implement one of the modeled strategies with their students. One example from Module 2 asked the teaching fellows to reflect on how they used language in the classroom that day and how it helped their learning. During the initial program year, these reflections were shared with the researchers.

After the modules were developed, the content was first piloted with in-service middle grade STEM teachers from the urban school district where the fellows would complete their teaching assignments. These educators, some of whom later acted as mentor teachers to the teaching fellows, attended a pilot session to evaluate the sample content and activities for their appropriateness in their diverse middle school science classrooms. Following the evaluations by the in-service teachers, the modules were revised and finalized. To build capacity for the MAT program faculty, the educational linguists recorded the modules and held workshops to train the university instructors who would be teaching the content. Additionally, the educational linguists attended the in-class presentations of the modules during the first year of the program to observe implementation. The modules were then revised based on the feedback from the lead faculty of the science pedagogy courses, observations of her instruction, and student responses to the material.

3. Findings from Three Educator Groups

3.1. In-Service Middle Grade STEM Teachers

As discussed earlier, the module materials were initially piloted with a group of 15 in-service middle grade STEM teachers in a full-day workshop. The group was selected to be representative of the classrooms in which teaching fellows would be working. In addition to presenting information about CLD students, the researchers facilitated sample activities from the modules. After each activity, the participants evaluated the activity based on whether (a) they thought they could use the activity in their classroom and (b) the activity would help their students to develop language and literacy skills. They were also invited to add modifications or content ideas for their own classrooms. Before the session, the participants were asked if they had had any prior training related to CLD learners in
the science context. Of the 15 teachers, one indicated that she had previously been enrolled in a Master’s-level class covering differentiation; the rest had never had this type of PD or coursework. The participants were also asked if they currently modify their instruction for CLD learners; six answered affirmatively.

Eleven activities were piloted with the in-service educators. While each activity cannot be expected to match each teacher’s pedagogical style or their students’ needs, Table 2 shows that the majority of teachers agreed that each activity could be useful in their science classroom and benefit their students’ language and literacy skills. The teachers also added a total of 87 different ideas for how to modify the activities for their own classrooms. The modifications ranged from procedural suggestions, such as group size, to content ideas, such as using a visual literacy activity called “generating sentences” for learning the periodic table of elements or for comparing and contrasting plant and animal cells.

Table 2. Mentor teachers’ evaluations of module materials.

<table>
<thead>
<tr>
<th>Activity/Strategy Name</th>
<th># of Teachers (/15) Who “Could Use This Activity in Their Classrooms”</th>
<th># of Teachers (/15) Who Said “This Activity Would Benefit the Language and Literacy Skills of Their Students”</th>
<th># of Teachers (/15) Who Added Modifications to the Modeled Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside/outside circles</td>
<td>15</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Sentence stems</td>
<td>13</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Numbered heads together</td>
<td>14</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Traveling jigsaw</td>
<td>14</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Four-square poster</td>
<td>15</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Extended anticipation guide</td>
<td>14</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Expository text frame</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Most important words</td>
<td>13</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Round robin writing</td>
<td>13</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Snowballs</td>
<td>14</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Generating sentences</td>
<td>14</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

Mentor teachers’ overall feedback was also analyzed according to the core components of the modules. In terms of understanding the language of science, the teachers demonstrated a willingness to incorporate language and literacy in their STEM instruction. One teacher highlighted that the best aspect of the PD session was “mostly the different ideas of how to teach language through content”. For CLA, the participants highlighted the importance of peer-to-peer interaction for language development. One teacher identified one of the key aspects of the workshop as “methods to get everyone comfortable and feel comfortable participating”. Another mentioned the importance of getting to know students’ backgrounds by stating that he would modify an activity through “culture” by making the examples “more familiar and relevant”. With regard to pedagogical modeling, most teachers specifically named at least one activity they would use with their students. They appreciated the “teacher-friendly modeling” and “working with different peers”. One teacher commented, “I love being able to do the activities so we could see how they work and if you need to modify”. They especially appreciated “science-specific scenarios” that “relate to the content we teach”.

3.2. University Faculty

After the initial pilot, teaching faculty from the partner university were trained on the module content via a half-day PD workshop. This group included faculty members from the Division of Sciences and Mathematics and from the Division of Education, who were key personnel in the MAT program. The goals of this session included soliciting feedback
on the module lesson plan format itself, as well as providing a preview of the research-based linguistic principles of the curriculum. Faculty from the Sciences and Mathematics division in particular remarked that the information on academic language was new to them but integral to student success. One faculty member commented that “academic language is a style that can be applied for academic success of students”. The participants indicated that the materials seemed applicable to teaching fellows’ needs. For example, one professor stated “some, if not all the candidates will know science terms but may not know or be used to words such as ‘pedagogy’ or ‘methods.’” Faculty also commented on the significance of the information for MAT programs across the entire Division of Education, asking “how we might generalize some of this (academic language) for all methods courses...implementing some common strategies across the program (and emphasis on English learners)”. Given this response, the educational linguists were invited to present similar workshops to faculty again in subsequent years.

After the initial workshop, a lead assistant professor of science education was designated to deliver the module content to the teaching fellows in both the fall and spring semesters. The educational linguists began to collaborate directly with her, coordinating the module delivery, answering content or lesson delivery questions, observing the class sessions, and eliciting feedback about teaching fellows’ comprehension of the materials and any suggested modifications.

3.3. Program Teaching Fellows

In the final phase of the project, the content was presented in the MAT program courses. The lead professor delivered the module content to the teaching fellows in 10 class sessions across three methods courses. At end of each of these 10 class sessions, the teaching fellows participated in some type of “tickets out” activity. As described above, these closing activities provided the fellows with opportunities for reflection on the session. Example prompts included “What are three key ideas and one question from today’s discussion?” and “What is one ‘aha’ moment, one activity you plan to incorporate, and one question you still have after today’s session?” These tickets out were deductively coded by the educational linguists using NVivo Pro 12 for Teams [43] to identify how the fellows’ key takeaways from the language modules connected the core components of the program (i.e., understanding the language of science, CLA, and pedagogical modeling). Our analyses found that most of the reflections from the teaching fellows were connected to one or more of the core components of the modules in some way and that they were “buying in” to the content, as they were asking thoughtful questions about language and literacy in the context of science and envisioning how they would use what they had learned with their own students. Four themes emerged from the tickets out.

The first theme from the teaching fellows’ responses was a strengthened understanding of the language of science. The fellows showed that they had started to think more consciously about language in their classrooms through comments about differentiating between content and language objectives. Reflections about vocabulary instruction included teaching various categories (Tiers 1, 2, and 3) of vocabulary [44] and spending more time on words with multiple meanings. Further comments demonstrated that the fellows had begun to recognize that language goes beyond vocabulary, with multiple tickets out acknowledging the importance of considering language at the discourse, sentence, and word levels. One fellow shared that “language is not just about vocabulary”. The fellows also indicated that they had begun to think about incorporating all four language domains into their instruction and creating opportunities to use those domains through group activities. This illustrated deeper awareness of the complexities of scientific language and how they could foster it in their classrooms.

A second notable theme related to teaching CLD students. These responses reflected the teaching fellows’ linguistic understanding of valuing and leveraging students’ linguistic resources as well as growing CLA. Several comments focused on supporting students who speak languages other than English at home, ranging from differentiating instruction.
and activities to ensuring that they are thinking about comprehensible input in their instruction. One fellow shared that they plan to be more “mindful of classroom language; not everyone understands English and content-specific language”. Others discussed their new understanding that peer interaction and group work is important in supporting the language development of CLD students and expressed that they now see translanguaging as a vital tool to support multilingual and multidialectal students.

Another recurring theme highlighted connections with CLA. One fellow noted the importance of knowing each students’ background, including their language experiences, and another expressed that it is necessary to consider each student when constructing a lesson plan. An additional reflection exemplified a fellow’s increased self-awareness related to cultural and linguistic diversity: “What we plan as teachers may not serve students well, since the plan is seen through our own lens, i.e., what we already know”. Several comments demonstrated that many fellows had begun to think of themselves as a teacher of language as well as content.

Finally, all the teaching fellows shared comments that reflected the impact of pedagogical modeling. In some remarks, they discussed new understandings of classroom instruction practices. These comments included considering differentiation in instruction and activities; being deliberate in their selection of texts, scaffolds, and target vocabulary; and increasing opportunities for group work. Other responses referenced specific activities that the fellows intended to incorporate into their future instruction. Some of these comments simply cited an activity they believed would be beneficial in their science classroom, while others made explicit connections to how those activities would support their students’ academic language development. One of the teaching fellows noted that the “pick and switch” activity stood out, because it incorporated all four language domains. Another fellow highlighted the ways in which the “dominoes” activity supported both content and language development, stating “It shows students how to work as a team and work with numbers. Also, adding questions to the activity allows students to hear from another student to help each other learn”. These responses illustrate how incorporating pedagogical modeling into the modules allowed the fellows to envision integrating language and literacy into their own instruction.

4. Discussion

Throughout the development and implementation of the project, fostering educator buy-in was a priority. This process began in the piloting stage, where materials were shared with different groups to ensure that they were appropriate and beneficial for middle grade science teachers (in-service teachers) and that they would align with the MAT program’s structure (teaching faculty). The materials were revised based on feedback from these pilot activities, as well as from the lead faculty member and teaching fellows during the first year of implementation, further promoting buy-in by making the process a collaborative effort with stakeholders from diverse backgrounds [7].

One key aspect of facilitating buy-in was building a strong relationship with the lead professor. She expressed being initially “overwhelmed [because] . . . I didn’t have any experience with viewing scientific language through a linguistics-based lens” [45]. She referred to the collaboration as a “learning opportunity” but “with a huge learning curve” [45]. However, she quickly took ownership of the material, teaching the content with fidelity while also making modifications as needed (e.g., adjusting activities for smaller group sizes and breaking up modules into multiple class sessions). The lead professor later reflected that she found herself “listening to the recorded versions of the presentations on my drive into work and just really delving into the research literature that was associated with the learning materials quite deeply so that I could enhance my own knowledge”. She also reported finding “solace” in the linguists’ support [45].

The tickets out during piloting and the first year of implementation also provided evidence of buy-in, as all three groups of educators discussed modifications of strategies and activities for their own students and content, indicating that they were reflecting on
their own classrooms and contexts vis-a-vis the language and literacy material. Creating a partnership that valued the educators’ input helped to reduce possible resistance and ensured the materials were relevant to their specific contexts. The elements of learner autonomy, collaboration, reflection, and instructional relevance were intentionally integrated in the project and module design and have been shown to be key aspects that allowed for sustained, even transformative changes in educators’ practices [21].

Both the teaching fellows and lead professor went beyond buy-in and took ownership of the language and literacy content by presenting it at state and national education conferences. By the end of the project period, the lead professor co-presented with the educational linguists at several science educator conferences, e.g., [46]. Two of the educational linguists also co-presented with the lead faculty member and five of the fellows at two additional conferences, a state science teachers’ conference [47,48], and a national summit on education [49]. During each of these presentations, the fellows shared pedagogical activities that incorporated language and literacy into science content and explained the benefits they had observed by doing this with their own students. By appropriating the module content and making it their own, the fellows not only displayed buy-in but began to situate themselves as experts on embedding language and literacy into science instruction. The collaboration with the lead professor continued as she invited the linguists to write a chapter for a book that she co-edited on STEM education in the urban classroom [39].

Despite the evidence supporting science educator buy-in and the implementation of language and literacy content and practices, this project offers several lessons learned. First, post-workshop responses from the in-service mentor teachers and university faculty focused primarily on pedagogical modeling and the activities they envisioned using in their classrooms. The teaching fellows, on the other hand, shared feedback that connected to all three core areas of the modules (understanding of the language of science, CLA, and pedagogical modeling). The fellows had more intensive and repeated exposure to the language and literacy content, interacting with it during 10 class sessions over the course of a school year, whereas the mentor teachers and faculty participated in isolated workshops. This supports previous work that has pointed to the importance of sustained professional development rather than episodic training to support deeper reflection on content [20–22].

The findings also highlight considerations for future work in STEM educator training. While this study focused on the educators’ attitudes on linguistic diversity and their willingness to implement language- and literacy-focused practices, more research is needed on how integrating language and literacy content into educator training impacts K-12 students’ comprehension of and performance in STEM subjects. Additionally, although content on language variation was intentionally included in the module content, few participant responses focused on valuing vernacular ways of using language. The lack of uptake on this topic may indicate that the facilitation of the module content focused more on multilingual students as opposed to students who speak vernacular varieties of English. Moreover, the recent attention to multilingual learners in educational linguistics, PD, and federal and state legislation likely magnified the focus on that student group. This further suggests that the content on language variation and linguistic equity should be amplified and discussed regularly as part of teacher education and PD. As Mallinson [15] argues, effective teacher preparation programs should provide educators not only with linguistic knowledge but also with specific information about local language varieties and community norms. While the module curriculum elicited these discussions and the researchers themselves participated in discussions of linguistic bias against AAL or regional dialects, research has shown that both White and Black Americans often judge speakers of AAL more negatively in professional settings, e.g., [50,51]. Thus, while the teaching fellows identified as Black, there is still a need to unpack linguistic biases of social, regional, and racial dialects in teacher education.

Another limitation to this project is that it was not designed as a research intervention. Thus, the data collected were limited to discussions with program faculty and the “tickets out” rather than summative program data or classroom observations of the teaching fellows.
Since the creation of the project materials 10 years ago, the field of education has become more aware of systemic biases and there has been substantial movement toward supporting social justice through CLA. Thus, the content that was implemented during the initial stage of this project can and should be revised to meet current needs and understandings. As the module materials are still being implemented in three courses within the MAT program [45], the authors are currently working with the university partners to update content, including course readings, to ensure the continuous improvement of the program content.

As language and literacy demands increase at the secondary level, students are asked to be “mini scientists”, with social equity implications for ensuring that all learners are prepared for the authentic disciplinary practices of adulthood and future careers [52] (p. 1). Before students can achieve their potential in STEM fields, however, teachers and teacher educators must be aware of the language and literacy embedded within the disciplines and how to teach CLD students. This project’s collaborative approach to embedding linguistic awareness and practices into a teacher preparation program is a promising step towards promoting linguistic equity in STEM education.

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**Institutional Review Board Statement:** While our project did include information gathered from human subjects, this information was collected for program development purposes. We were not gathering information about the participants themselves, nor were we looking at any outcomes related to participants; rather, we were asking them for commentary about the content in our specific program modules. Furthermore, this feedback was optional and did not require them to share any personal information. Thus, our paper does not include data that would meet the Office for Human Research Protections definition of research: “a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge”. The feedback gathered was not part of a systematic investigation, nor was it meant to contribute to generalizable knowledge; it was used for feedback and refinement of specific program materials.

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