Balancing the communication equation: An outreach and engagement model for using sociolinguistics to enhance culturally and linguistically sustaining K–12 STEM education

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To mitigate systemic culturally and linguistically rooted barriers to STEM achievement, particularly for African-American students, implementing linguistically and culturally sustaining approaches to STEM education is critically relevant. This article presents an engagement model for using sociolinguistics to enhance K–12 STEM education, drawing upon research carried out with K–12 STEM educators who attended workshops on language variation and subsequently participated in semi-structured interviews and a focus group. Findings indicate the centrality of integrating linguistics into K–12 STEM teacher preparation, in order to advance educational equity for all culturally and linguistically diverse students.*

Keywords: sociolinguistics, culturally responsive education, STEM education, multicultural education, African-American English, teacher preparation

1. INTRODUCTION. Decades of linguistic research have demonstrated that listeners across various social and demographic backgrounds frequently hold particularly strong negative attitudes about African-American English (AAE) and its speakers (Tucker & Lambert 1969, Preston 1998, Gupta 2010). These ideologies about AAE and African-Americans themselves are no less strong in educational contexts. From early cognitive-deficit hypotheses to contemporary tests such as SATs and GREs that are written in a linguistic style most familiar to White middle-class students and designed to measure things they know well (Feagin 2000, Charity Hudley & Mallinson 2011), to the fact that many educators hold disproportionately negative attitudes about AAE (Adger et al. 2007, Delpit & Dowdy 2008), research finds that the academic and linguistic deck is stacked against African-Americans. In addition, the culture of STEM is not always aligned with the cultural and social values of African-American students, which can lead them to 'opt out' of STEM learning contexts due to differences in value systems (see Seymour & Hewitt 2000, Laursen et al. 2010, Beasley 2011).

Communicative differences can be a significant contributor to educational inequality, but effective teaching is essential to mitigate it (Adger et al. 2007). Accordingly, linguists have called for engagement and outreach with K–12 educators and schools to raise linguistic awareness, based on the premise that educators who understand language variation and who can implement culturally and linguistically sustaining teach-

ing are better prepared to serve diverse students and address educational barriers (see e.g. McKay & Hornberger 1996, Denham & Lobeck 2005, Labov & Baker 2005, Reaser 2006, Sweetland 2006, Adger et al. 2007, Reaser & Wolfram 2007, Rickford & Rickford 2007, Brown 2009, Charity Hudley & Mallinson 2011, 2014). Language is central to dynamics of teaching and learning, and the US student population is increasingly diversifying—even as the demographics of the educator population remain stable at roughly 82% White and predominantly female (National Center for Education Statistics 2013). To date, linguists have utilized various methods for linguistic and educational outreach. Some have developed K–12 curricular materials (e.g. Labov & Baker 2005, Craig & Washington 2006, Wheeler & Swords 2006, Reaser & Wolfram 2007, Brown 2009, Pippin & Denham 2012) and studied their use in classrooms (see e.g. Sweetland 2006, Honda et al. 2010, Henderson 2016). Others have taught teacher-training programs (e.g. Godley et al. 2006, Godley et al. 2015). As Strickling (2012:78) writes, 'in light of the need for a linguistically informed school community', linguists must consider 'how this goal is best accomplished and the depth of sociolinguistic knowledge required for it to be useful to educators'—which includes the question of how and when teacher training should be introduced.

Although educators at all levels need preparation to help them work with students from diverse cultural and linguistic backgrounds (particularly when they differ considerably from the teachers' own), such training is not always readily available; indeed, it is often scant. As Godley and colleagues (2006) report from their survey of language arts educators, nearly one third had NEVER taken a course on linguistics or language diversity. One can readily imagine that percentage is far higher for educators from non-language arts disciplines—particularly in STEM fields, which include science, technology, engineering, and mathematics. Thus, the primary question we faced when considering the complex issue of how to integrate sociolinguistics into professional development for K–12 STEM educators was how to take the first linguistic step and start the conversation more broadly.

1.1. PREPARING STEM EDUCATORS TO SERVE CULTURALLY AND LINGUISTICALLY DIVERSE STUDENTS. To date, linguists have overwhelmingly done K–12 outreach with humanities-related teachers, to the near exclusion of those in STEM. Yet students do not leave their language patterns or beliefs at the door when they enter STEM classrooms, and neither do educators. Information about how STEM teaching and learning are affected by language variation and approaches to linguistic diversity is critical, given the fact that African-American students and students from other traditionally underrepresented groups are often underserved in STEM fields and careers (Committee on STEM Education National Science and Technology Council 2013). But STEM educators may not realize that linguistic issues are critical in their classes and may be unprepared to address them (Lemke 1990, Lindholm-Leary & Borsato 2006). In order to develop the competencies to make linguistically and culturally sustaining STEM teaching a reality, particularly for African-American students, these educators need accurate, precise, and situated linguistic knowledge that is pedagogical as well as social and cultural. This includes knowledge about language variation in general, as well as specific information about the language and cultural practices of local student populations and speech communities. We further maintain that such knowledge must explicitly address linguistic and cultural racism and bias in particular educational contexts, including STEM.

STEM scholars and educational organization leaders have noted the need to prepare STEM educators to serve culturally and linguistically diverse populations (e.g. Leder-

man et al. 2001, Rhoton & Bowers 2001). Funding sources including the National Science Foundation (NSF) and others have responded by providing support for initiatives that prepare educators, such as the NSF Noyce Scholars Program (http://app.nsfnoyce .org/). This work has resulted in a growing literature demonstrating the use of culturally responsive teaching techniques in STEM—including in chemistry (Collins et al. 2012), computing (Eglash et al. 2013), and general science (Emdin & Lee 2012). Most of these approaches tend to center on culture broadly defined, however, and generally do not focus on language specifically. Further, existing STEM professional-development approaches that do directly seek to build educators' cultural and linguistic competence are often tailored for English language learner/emergent bilingual student populations (e.g. Villegas & Lucas 2002, Lee et al. 2004, Rosebery & Warren 2008, Hakuta 2014, Noble et al. 2015). Bianchini and colleagues (2002) emphasize the need to more expansively address language, identity, and social justice in STEM faculty professional development, particularly because these issues influence the beliefs and ideologies of K–12 educators. Along those lines, Bryan (2003) reports on a 'connectivist' model of STEM professional development, which incorporates the identity and beliefs of educators into the development of their STEM practice. These approaches have not yet become prevalent in STEM, however, and widespread reforms for African-American students have largely failed in impact (Berry et al. 2014).

1.2. A sociolinguistic model for K–12 STEM outreach and engagement. To contribute to the conversation about incorporating sociolinguistics into K–12 STEM teaching, in this article we present our model for sociolinguistic engagement with in-service K–12 STEM educators. In-service educators are currently teaching; this means they are already situated within a particular pedagogical context, with its own constraints and structures. With regard to STEM educators in particular, as Walker (2007: 113) explains, they may face multiple expectations, the reality of which must be balanced in models of professional development:

> [These teachers] balanc[e] a number of sometimes competing requirements in their teaching: adhering to mathematics reform initiatives in their school, district, and/or state; meeting the expectations of principals and parents; and finding ways to ensure that their students are able to perform adequately on standardized tests that have significant ramifications for teachers and students if students fail.

Because they are already teaching, in-service teachers are also already engaged with issues of linguistic and cultural diversity, which unfold in their classes, in real time, in varying ways. Within schools in the US South, where our work has predominantly been located, we had to take into account the fact that race and racism can present a particularly challenging dimension. Conversations that start with race as the topic can cause fear in some educators and can cause others to bristle. At the same time, these conversations must be had; racism cannot be effectively stopped by showing educators charts or measures that indicate their racism, nor can the problem be solved by giving them tests or assessments. Furthermore, the concept of African-American English itself is still new to many educators, particularly in the STEM fields. Our work, which intended to directly reach Southern US K–12 STEM educators, therefore needed to take a situated approach that would respect the potentially competing interests and challenges that these educators bring to the table—cultural as well as pedagogical.

Our solution was to take an empathy-centered, community-based, participatory-focused approach to professional-development workshops with K–12 STEM educators that was designed to help them think about language as a framework, into which particular information about African-Americans and about teaching and learning in STEM is

then woven (Charity Hudley & Mallinson 2014, 2016). This approach allowed us to facilitate conversation that moved more fluidly between the racially/culturally specific and the pedagogically general; it also derived from our more general model of professional development for educators, designed to build relationships that can be sustained over time (see Mallinson et al. 2011). In our model, through the vehicle of collaborative teacher-preparation workshops, the voices and insights of educators themselves are placed at the center of the inquiry. We draw upon educators' and students' 'funds of knowledge' (Gonzalez et al. 2005)—that is, the knowledge, skills, and experiences they bring with them to the classroom—and use these insights to design and implement educator-generated strategies for change. Thus, we foster critical reflection among K–12 educators, while also emphasizing practical application. As the professional-development literature indicates, such approaches hold the greatest promise for changing teaching practices and affecting educational policy, as they occur in contexts in which teachers are already in collaborative pursuit of questions applicable to their own work (Little 1993, Lieberman 1995).

Our study adds to what linguists know about K–12 STEM educators' experiences with language and culture, with an emphasis on how they view sociolinguistic insight as applying to their teaching. The knowledge we gained allows us to better tailor our message not just for STEM educators but for all educators. We demonstrate how these educators learned about language variation and about how linguistic and cultural factors may affect African-American students in STEM contexts particularly, as well as how language use and language discrimination can perpetuate advantage and disadvantage in schools more broadly. These practicing educators were adept at seeing the connections between such knowledge and their experiences working with culturally and linguistically diverse student populations. This insight fostered teacher reflection in ways that disrupted linguistic ideologies and promoted the development of positive attitudes toward language variation. It also positively impacted the ways these educators thought about their pedagogical approaches and encouraged them to consider making changes to the teaching and assessment of their culturally and linguistically diverse students, particularly African-American students. Overall, our findings suggest that, with a greater understanding of culture and language, K–12 STEM educators can more comprehensively recognize and address the linguistic, educational, and social factors that can create barriers to success for African-American students.

In addition to the more general goals that are largely focused on STEM educator insight and application, this article goes further in also focusing on sociolinguists. In particular, through this work we suggest how those in our field can more meaningfully and effectively work with STEM educators, guiding them to understand and appreciate the relevance of language and culture in their own teaching, so as to benefit all students and in particular African-American students. With situated knowledge about the interplay between the symbolic and structural effects of language, sociolinguists who seek to do educational engagement work are better able to tailor our ideas about language to our audiences, including K–12 educators from specific disciplines. Our work thus bridges gaps between the multicultural education movement, sociolinguistics, STEM teaching and learning, and the field of teacher professional development, as we investigate how knowledge about language variation can be marshaled to help educators understand and address opportunity gaps in STEM education.

2. Doing culturally and linguistically sustaining STEM teaching: a focus on african-american students. A primary focus of the literature on US multicul-

tural education and culturally sustaining teaching is that understanding the dynamics of race, ethnicity, and culture is critical for student engagement and student success, such that African-American and other traditionally underrepresented students can be better served in K–12 and higher education (see e.g. Gay 2000, Cazden 2001), including in STEM fields (Ebby et al. 2011). As Reddick and colleagues (2005) assert, in order to make STEM relevant to culturally and linguistically diverse students and thereby promote their engagement and achievement, it is necessary to follow the principles of inclusive education, which proceed from the culturally responsive teaching movement (Gay 2000). At the same time, because the terminology of culturally responsive teaching and/or multicultural education remains unfamiliar to many STEM educators, the relevance of incorporating these perspectives into their teaching may not be immediately apparent to this population (Reddick et al. 2005).

Although culturally responsive teaching can be viewed as 'just good teaching' (Ladson-Billings 1995), it is particularly fundamental to the achievement of African-American and other historically underserved students. Ladson-Billings (1995:160) identifies three criteria that comprise culturally relevant pedagogy: developing students' academic success, cultural competence, and critical consciousness. To develop these qualities among their students, educators of all backgrounds must take culture into account. In many instances, this means learning more about the concepts of language and culture so as to integrate them into teaching. Brown (2006) conducted an ethnographic study of fifth-grade African-American students in Detroit, Michigan, and found that the teacher's method of explaining science ideas by using AAE as well as academic language (in a science register) helped scaffold students' discourse and develop their science literacy. Brown and Spang (2008) further revealed how this teacher taught African-American students to explain and describe scientific concepts using both vernacular ('everyday') and scientific language, improving comprehension. Similarly, Johnson and colleagues (2013) examine how a second-year math educator used AAE features and rhetorical styles (including *ain't*, call-and-response techniques, and rhythmic patterns, along with other African-American cultural practices) to affiliate with his students and increase STEM relevancy, which improved their engagement with and learning of the material. In other situations, even indirect modeling of language variation can facilitate STEM engagement among linguistically diverse students. In the context of higher education, Dunstan (2013) found that Appalachian students (primarily White, with one African-American) who attended a large Southern US university felt more comfortable in animal science, agriculture, and civil and mechanical engineering because those fields tended to attract students and professors from rural backgrounds; the students' comfort level increased their sense of belonging. Thus, students not only crave seeing scientists who look like them; they need to hear scientists who sound like them too.

Educators at all levels need linguistic and cultural information and strategies to engage and support diverse students, whether or not students' linguistic and cultural backgrounds match their own. Yet many educators feel inadequately equipped to understand the linguistic and cultural backgrounds of their nonstandardized English-speaking students. Gupta (2010) investigated elementary-school teachers' beliefs about AAE and their preparedness to address the linguistic needs of their African-American students. More than half of the educators in her study believed that students who speak AAE will have communication problems in the classroom. At the same time, the respondents stated that they had never been offered any teaching strategies that would help them address these challenges. Linguistic research finds that these challenges may include disproportionate conversational burdens that can affect students on personal and psychological

levels (Charity Hudley & Mallinson 2011, 2014, Lippi-Green 2011). Classrooms can also be sites where students experience LINGUISTIC MICROAGGRESSIONS (Charity Hudley & Mallinson 2014), a term derived from the broader concept of microaggressions, which refers to everyday biases and indignities faced by members of marginalized groups (Sue 2010). Speakers who absorb linguistic microaggressions and other negative messages about their language can experience linguistic insecurity when communicating (Labov 1972), which can be particularly damaging in educational contexts. Linguistic microaggressions—which are rooted in and reflect broader ideologies—can also interact with other microaggressions such as those based on ethnicity, gender, sexual orientation, and more to perpetuate inequalities (Alim & Smitherman 2012, Charity Hudley & Mallinson 2014). These factors contribute to broader deficit-oriented discourses about African-American students' potential to learn, which is a major contributor to educational inequality, particularly in math and other STEM fields (Martin 2006, 2012, Berry et al. 2011).

In addition to overt and subtle sociolinguistic factors, structural linguistic factors can also affect STEM learning. Scholars have identified a masculinized, European, middle-class mode of discourse that prevails in STEM settings (Busch-Vishniac & Jarosz 2007, Foor et al. 2007), which perpetuates notions of an 'idealized' student (Santa Ana 2002); such discourse can have a gatekeeper effect that reinforces hierarchies and inequalities in STEM (Moore 2007). Academic language further represents a disproportionate barrier to STEM learning for students from underrepresented groups. Abedi and Lord (2001) found that emergent bilingual students performed 10 to 30 percent worse on math word problems than on those presented in a numeric format, and similar trends are well attested in the literature (Lemke 1990, Wellington & Osborne 2001, Schleppegrell 2004, Lindholm-Leary & Borsato 2006, Morgan 2006). In addition, structural linguistic issues can affect students who are native speakers of nonstandardized varieties of English, including AAE (see Charity Hudley & Mallinson 2014). STEM teaching and learning heavily depend on students understanding relational terms, such as *next to last*, *below*, and *until*, but these terms often pose disproportionate challenges for students who also have limited experience with School English (Charity et al. 2004). Students from these backgrounds are less likely to be aware, without being taught, that terms such as *sum* and *subtract* may be used as synonyms for the more common phrases *put together* and *take away* or that terms like *solve for*, *find*, and *evaluate* may be used interchangeably. Specialized verbs, such as *calculate*, can pose challenges too, particularly when STEM educators do not explicitly teach students about contrasts in vocabulary words (Wellington & Osborne 2001).

Other linguistic issues that can disproportionately affect students who have less experience and familiarity with academic English include the routine use of such features as the passive voice (as in phrases like *chemical changes are added and subtracted*), nominalization (as in *the first increase is by five*), and high lexical density (as in *the model rests on the localized gravitational attraction*) (Halliday & Martin 1993, Morgan 1998, Wellington & Osborne 2001, Snow & Uccelli 2009). Schleppegrell (2007) points to conjunctions used in technical and precise ways—for example, *if*, *when*, and *therefore* in word problems, theorems, and proofs. Grammatical variation can also affect student performance on texts and test questions. Terry and colleagues (2010) examined the linguistic complexity of math word problems and success in carrying out computations for seventy-five African-American second graders. They found a statistically significant effect for the variable use of possessive -*s* and third-person singular -*s*: 15% of students would have answered about 9% more questions correctly if the questions had

been worded in such a way as to not contain those linguistic features. They suggest that some students who speak AAE may face an added cognitive load on working memory when they read and process math word problems—and time spent translating while taking tests is time lost. Gilchrist (2013) extends this model, finding challenges with math word problems among African-American college students.

Linguistic and cultural awareness can help educators avoid or address these types of challenging situations, even subtle and inadvertent ones, whether cultural or linguistic-structural. From a linguistically sustaining educational approach, students' rich and varied identities must be viewed as resources, not as deficits. Educators with robust cultural and linguistic knowledge are better prepared to support and incorporate the backgrounds of nonstandardized English-speaking students as part of providing them with the social support and academic tools to succeed. In addition, all educators, including STEM educators, must be included in broader conversations about academic language and literacy, so that these issues are not left to either linguists alone or to educators from the language arts.

Our research focuses on K–12 STEM educators who have attended workshops in which we discussed principles of language, literacy, and culture, specific to working with African-American student populations. The long-term ambition of our study is to add to what we know about how linguists and educators can work together to understand linguistic, cultural, and social ideologies within STEM contexts and to address the pedagogical challenges and educational inequalities that can emerge as a result. Within that goal, our present study explores K–12 STEM teachers' insights into and experiences with language, literacy, and culture—illuminating the centrality of language to the pedagogical beliefs and practices of K–12 STEM educators and giving additional, STEM-centered context to findings from Gupta (2010). As our evidence suggests, when attuned to issues of linguistic diversity, K–12 STEM educators are able to build on their strengths as dedicated teachers and more effectively engage in culturally and linguistically sustaining education. K–12 STEM education is therefore a prime site for increased engagement by linguists who seek to advance educational equity via teacher partnerships. Our goal is for them to then share, in turn, more pertinent and tailored information with other K–12 educators.

3. Methods. This study focuses on twenty-eight K–12 STEM educators from schools in Maryland and Virginia.[1] These participants are a subset of a larger group of sixty educators who worked with us in educational and research partnerships from 2009–2014, when we developed and led a series of 'Language Variation in the Classroom' workshops for hundreds of K–12 educators from public and independent schools, located primarily in Maryland and Virginia. Those general workshops—which integrated sociolinguistic information into a framework of multicultural education, applied across content areas—were designed based on conversations with K–12 educators who felt they needed more information or confidence to work with culturally and linguistically diverse students (Mallinson et al. 2011).

3.1. Workshop detail. In 2011, we received a research grant from the NSF to investigate understanding of language differences, pedagogical practices, and student assessment related to linguistic diversity among K–12 STEM educators in Maryland and

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[1] Institutional Review Board (IRB) coverage was obtained through both authors' institutions, protocol numbers Y10CM27129 (UMBC) and PHSC-2013-02-24-8499-ahchar (College of William & Mary). All participants completed consent forms prior to all workshop attendance and any subsequent participation in the research study.

Virginia (Mallinson & Charity Hudley 2011–2015). As such, we developed workshops that, while dovetailing with our broader 'Language Variation in the Classroom' initiative, were tailored for STEM educators (Mallinson & Charity Hudley 2014, Charity Hudley & Mallinson 2016). We recruited STEM educators, particularly targeting the greater Baltimore (MD) and Hampton Roads and Richmond (VA) areas, where schools serve sizable populations of African-American students. Between Fall 2011 and Summer 2013, we held ten one-day workshops, four in Maryland and six in Virginia, usually in a conference room at one of our home institutions. Generally, about five to seven educators attended, which allowed for discussion and reflection. Both authors co-led most of the workshops, although a couple were led by just one author. Participants who completed the workshop received a $50 honorarium as part of our NSF grant and a copy of our book on language variation and education (Charity Hudley & Mallinson 2011).

   As we mention throughout this article, the fact that we were guided by the principles of community engagement and participatory research models was crucial (Cress et al. 2013). We held the workshops before we invited the educators to participate in the research portion of the study, for two reasons. First, as we use a community-based participatory research model in order to obtain greater educational linguistic justice, we wanted to ensure that participants had time to get to know us, to become comfortable with us as researchers and workshop deliverers, and to become comfortable with the prospect of sharing their own experiences and insights. Second, we wanted participants to have the opportunity to learn and become familiar with specific sociolinguistic information and terminology well before any interviews would take place. STEM teacher preparation in language, literacy, and culture is atypical. As such, by making sure that we taught any sociolinguistics-specific information to participants prior to interviewing them, we laid the groundwork for common understanding. We also avoided placing teachers in the potentially anxiety-producing situation of being interviewed about specific academic concepts or linguistic particulars that they may otherwise have little knowledge about—an ethically problematic situation that can also produce empirically problematic results.

   Moreover, we felt strongly, within a linguistic justice framework, the need for all of the educators who attended our workshops to receive critical information about language, culture, and STEM, regardless of whether they agreed to participate in the follow-up research portion of our study. As such, our workshops served as a method for us as sociolinguists to give back to the K–12 educational community (Wolfram 1998). Community partners are central to our model because we are seeking to determine how interested educators respond to and integrate sociolinguistic information into their pedagogical frameworks and experiences, so that we can best integrate and tailor information from STEM education to their specific ideologies and their specific teaching needs. It is important to note that our model would be different for so-called resistant educators than for the ones we focus on here, who are actively seeking out knowledge that has not already been provided for them.

   In the first half of our workshops, participants were guided to think about whether they were aware of achievement differences and/or opportunity gaps related to linguistic and cultural variation, and we discussed the specific relevance of language variation to STEM education. Participants learned to identify specific examples of language variation that cause educational concerns for students, across various grade levels and content areas. This approach across grade levels was important, as our participants often taught more than one grade and/or content area; for instance, one taught third and fifth grade; another taught tenth-grade geometry and computing. This instructional breadth

made it difficult to tally our participants by grade or discipline but increased the likelihood that they would find the workshop content relevant to their teaching.

In the second half of our workshops, participants learned about effective strategies to address variation in students' speech and writing, and they brainstormed ways to tailor these strategies to their own classroom settings. Finally, participants were guided to think about sources of linguistic and cultural inequality in their classrooms or schools and how to address these issues. Throughout the workshops, educators shared how material on language diversity directly related to their pedagogical beliefs and practices. This format ensured that the educator participants had a common place of understanding from which we could all share information and talk about issues of language and culture.

3.2. DATA COLLECTION AND ANALYSIS. Given the complex sociocultural processes involved in ascertaining and understanding individuals' attitudes, beliefs, knowledge, experiences, and skills, particularly in the context of teacher education, research methodologists suggest using combinations of complementary data-collection techniques (Desimone et al. 2002, Day et al. 2008). Whereas surveys provide broader insight into participant opinions, interviews are well suited for capturing critical reflection and changes in beliefs, attitudes, and practices (Wengraf 2004). In addition, focus groups can reveal interactional dynamics among participants that may not surface through surveys or one-on-one methods such as interviewing (Morgan 1996). We followed these recommendations, obtaining data using multiple methods: pre- and post-workshop surveys, follow-up semi-structured interviews, and a follow-up focus group.

Our research design is not directly about assessing changes in the practices or teaching of the educators immediately after the workshop. The workshops themselves are not the single-shot educational intervention; rather, they are the conduits for communicating particular sociolinguistic information to participants, who then integrate this information with their other insights and experiences, thereby setting the stage for application and/or changes in teacher beliefs. In other contexts, it may be easy for educators to determine what is the 'right' answer, or to immediately incorporate a discrete set of new teaching techniques. Incorporating information about language and culture may not be as linear, however. As our participants demonstrate in their own words, it often requires dismantling old models and ideological approaches. It is a complicated process, and not always complete. Therefore, in order to advance educational equity particularly for African-American children, who, as Berry and colleagues (2014) maintain, have largely been failed by current professional-development approaches in STEM, we must do the complex work of studying how educators grapple with information about language, race, and culture within their local classroom and school contexts.

A timeline of our research process is provided in Figure 1. In Table 1, we provide the questions that we asked participants at each stage of data collection (for this article, we focus on the interview and focus-group data, as it provided the fullest narrative detail from participants). Two to four months after the workshops ended, we collected information from a subsample of twenty-eight participants. Twenty of these educators participated in semi-structured interviews, and eight participated in a focus group. We allowed people to be interviewed individually or in dyads as they felt comfortable, as is common in sociolinguistic research. As part of our NSF grant, all interview and focus-group participants received a $150 honorarium (in addition to the $50 honorarium and free book that they received for completing the prior workshop). Demographic data for these twenty-eight educators is provided in Table 2.

We purposely selected these twenty-eight educators from the larger pool of sixty participants. We took into account their demographic diversity, experience having taught
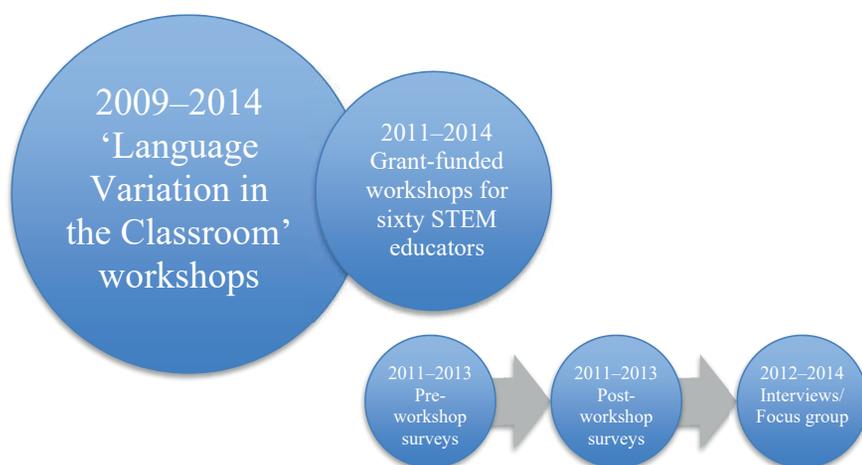
FIGURE 1. Timeline of the research process.

PRE-SURVEYS
1. What types of language variation have you noticed in your school and classrooms?
2. What kinds of professional-development workshops have you attended lately? What have you liked and not liked about them?
3. If possible, provide an example of a text or assignment that a student with language differences may struggle with.
4. What challenges concerning language variation do your students face—the use of different languages and/or varieties of English (if so, which)?
5. What topics would you like to see covered in this workshop?

POST-SURVEYS
1. What types of language variation have you noticed in your school and classrooms?
2. What challenges concerning language variation do your students face—the use of different languages and/or varieties of English (if so, which)?
3. What strategies or techniques would most help your students?
4. If possible, provide an example of a text or assignment that a student with language differences may struggle with.
5. Using strategies that you learned in the workshop on language variation and STEM education, how would you now approach your teaching?

INTERVIEWS
1. What role do you think that language plays in STEM education?
2. Do you think language is a challenge that African-American students in particular might face in STEM classes?
3. What challenges related to language do your students face? Is STEM-related jargon a problem for any of your students?
4. What do you remember most from our workshop on language variation and STEM education? How did it affect your teaching?
5. Have you made other changes to your teaching following the workshop? What strategies have you used that other teachers might benefit from?

FOCUS GROUP
1. Have you ever felt that a teacher had different expectations for students from a different language background?
2. What role do you think language plays in STEM education? Do you think language is a particular challenge for African-American students?
3. Have you used awareness of language variation or specific strategies to help your students? Are there any linguistic challenges that your students still face? How might you continue to help these students?
4. How do you think culturally and linguistically diverse students might interpret STEM-related standardized test questions differently?

TABLE 1. Questions asked in pre-surveys, post-surveys, interviews, and focus group.

	DEMOGRAPHIC GROUPS	MARYLAND (N = 19)		VIRGINIA (N = 9)	
		%	*N*	*%*	*N*
GENDER	Male	42.11	8	0.00	0
	Female	57.89	11	100.0	9
ETHNICITY	Asian-American	15.79	3	11.12	1
	African-American	21.05	4	44.44	4
	White/Caucasian	63.16	12	44.44	4
SCHOOL TYPE	Independent	10.53	2	11.11	1
	Public	89.47	17	88.89	8

TABLE 2. Demographics of twenty-eight K–12 STEM educator participants.

diverse STEM subjects, and availability to participate in the interviews/focus group. We also selected educators who had shared insights during the workshops that we wanted to explore further. Following these criteria ensured that our interview and focus-group participants were highly motivated to explore issues of language variation and STEM education more deeply; it also indicated their potential to work as future community-based research collaborators, rather than just serving as one-time research participants. Again, as noted, our community-based research model relies on educators who want to participate and learn. Because our participants primarily came to our workshops already having some prior insight that language, communication, and culture matter in STEM education and wanting to delve further into these topics, they were perhaps more inclined to engage in the follow-up portion of the study than might otherwise be typical. An additional challenge is to create materials designed to disseminate information about language and culture to all educators, not just those who seek out extra information via a research workshop. Nevertheless, the insights from this study are important as we develop materials for educators who want to learn more than simply what is required for certification or continuing education in their teaching area. Our model thus demonstrates one way in which linguists might enter a population with respect to equity and the interests of participants.

The interviews ($N = 20$) were conducted three to nine months after participants had attended a workshop. The fact that we were working with highly motivated educators was also beneficial for this stage of data collection. Allowing three to nine months to pass between workshop delivery and carrying out the interviews gave these educators ample time to think further about linguistic and cultural challenges in STEM, integrate information they had learned during the workshop into their teaching, and consider the successes and challenges of their pedagogical strategies. Interviews were semi-structured, each lasting one to two hours, as participants' time and schedules permitted. We provided a clear set of topics to be covered (see Table 1) while allowing the participant and interviewer to flexibly follow the conversation.

We held one focus group in Maryland, which lasted approximately two hours. It was attended by eight participants, which falls within the optimal size for encouraging active discussion and participant involvement (Morgan 1996). These participants were primarily selected according to similar criteria as for the interviews, with the additional criterion that they were willing to share views in a group setting. Table 1 provides the questions that we asked focus-group participants. We provided questions 1 through 3, whereas question 4 was a topic that focus-group participants brought up themselves. Because the focus-group participants worked in different schools, they wanted to discuss this issue of how STEM materials vary by institution, which materials are mandated versus optional, and whether some materials work better for culturally and linguistically diverse students than others.

The interviews and the focus group were fully transcribed by an undergraduate research assistant with previous transcription experience. To conduct our analysis, we triangulated the data from the interview and the data from the focus group and analyzed them following a grounded-theory approach (Glaser 1992), in which we engaged in substantive coding—a qualitative procedure that involves first open and then selective coding procedures (Holton 2007). Two broad themes emerged from the open coding process: (i) culture and communication, and (ii) the language of STEM teaching and learning. The open codes within these themes consisted of, respectively: (i) conflict, mismatch, bias, stereotyping, cultural competence, culturally responsive teaching, and student engagement; and (ii) reading, grammar, vocabulary, code-switching, texting language, test design, and other assessment. We then conducted a selective coding of the interview and focus-group transcripts, in which codes were refined and/or collapsed as necessary to capture the dimensions of the data. We engaged in line-by-line, iterative comparison of indicators to ensure that the properties of each category had fully emerged within and across the data; the process ended when we felt that no new properties had emerged and thus theoretical saturation had been achieved (Holton 2007). Per grounded-theory technique, to ascertain reliability in each author's coding techniques, we compared how codes had been applied across segments of the transcripts, using the 'constant comparison' method in which codes are inductively refined (Glaser & Strauss 1967). We also further cross-checked these insights against our notes from conversations that took place during the workshops themselves, to serve as a final source of data triangulation.

4. 'THERE MUST BE A BETTER WAY TO RESPOND': IDEOLOGIES, INTERACTIONS, AND DISCOURSE IN STEM EDUCATIONAL SETTINGS. To explore K–12 educator participants' experiences, attitudes, and ideologies about language standards and language variation, we introduced in our workshops Lippi-Green's (2011) concept of the communicative burden as well as our conceptualization of linguistic microaggressions (Charity Hudley & Mallinson 2014). With this framework, participants were guided to analyze the ways that communication practices and interactions can lead to linguistic inequalities within classrooms and schools. At first, many educators expected to learn about major misunderstandings and glaring cross-cultural conflicts. In fact, it is often in more nuanced interchanges—including microaggressions that educators may not even notice—that miscommunications and linguistic/cultural mismatches arise. In several interviews and the focus group, participants relayed their experiences with the subtleties of language and culture in STEM. Fiona,[2] a mid-forties White female upper-level math teacher from an independent school in Maryland, described in an interview a linguistic microaggression that she witnessed in her son's first-grade classroom:

> My son's first grade teacher, I used to go in the classroom to do some math with them. One of the kids, an African-American kid, was playing a game and he said, 'I don't got no dice.' He didn't have the materials he needed. And the teacher who was a young woman right out of college said, 'You know, Joshua, we speak English in this class.' Really harshly. And I just thought, oh gosh. There must be a better way to respond.

Fiona was very disturbed by what the first-grade teacher said to Joshua, she explained, because it set a tone that could encourage Joshua not to speak up at all. Indeed, Martin (2006) directly asserts, with regard to mathematics learning, that when African-American students' identities and cultures are validated by teachers, they are more likely to

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[2] Names of all educators and students are pseudonyms. Other potentially identifying details, such as school district and school name, have been omitted or disguised to ensure confidentiality.

learn and participate; when they are not, students are more likely to resist and disengage. As such scenarios illustrate, linguistic and cultural microaggressions and issues of bias are not intangible experiences; rather, they are manifested in—and responded to— through specific linguistic acts.

Evidence from our study further reveals what it sounds like when STEM educators send negative or shameful messages to students and how they contribute to larger educational issues. One of our participants, Keisha, an African-American female from Virginia, remembered a college biology class:

> On multiple occasions I would attend a professor's office hours and ask for help with understanding problems I got wrong on an exam. He would say things like, 'I can't believe you got that wrong. It was easy, but you were only one of six students out of the whole class to get this hard question right. I don't understand how you could get the hard question and not the easy one!'

Perhaps the professor thought that he was giving the student a compliment, but the feedback made Keisha question her capability: if she couldn't get the easy problems right, what was the point of being able to do the hard questions or even trying them in the future? Linguistic microaggressions can be deeply intertwined with racial and gender biases and can directly affect how students perceive and experience assessment—particularly for African-American students who know that tests can inaccurately represent their aptitude and achievements. Martin (2006) makes a similar point, focusing on how deficit-oriented discourse specifically contributes to racialized learning experiences for African-American students. Martin identifies the language that educators use as a key contributor to reproducing and reinforcing stereotypes about Black students' underperformance in school (especially in math) and calls for researchers to more fully explore how teacher rhetoric about Black students' learning contributes to educational inequalities for African-American students in STEM.

In older grades, students may feel under surveillance based on their grammar. In wanting to teach the norms and conventions of academic English, educators may inadvertently assess students, formally and informally, in ways that disparage linguistic and cultural variation. Marley, a mid-twenties White public middle-school science teacher in Virginia, realized that she unintentionally set the stage for her students to experience linguistic microaggressions:

> I have kids that come from very different backgrounds from myself, so when they speak, they speak very different than I do. And so I was really big at correcting them, all the time. They'd be like, 'I ain't got my homework.' I'd be like, 'You mean you don't *have* your homework.' I would always do it in front of other kids, constantly, and I didn't realize what type of effect that could have on someone. Basically it's saying that their language isn't the right way that they should be speaking, even though their parents speak that way and friends speak that way. I'm not saying that I said it in a bad way, but still, I didn't realize what kind of effect it could have, like saying, basically, 'I'm smarter than you, you know, I speak better than you do. You need to learn how to speak like I do.'

Marley saw that linguistic microaggressions can surface in seemingly benign conversations, as students who are criticized for their language use may perceive that their family and friends are also being denigrated. African-American students who push to assimilate to mainstream academic culture to succeed in school, which may include trying to assimilate linguistically, can feel forced to pull away from their home communities (Carter 2007, Kinloch 2010).

Similarly, Sasha, a mid-twenties White public high-school math teacher in Virginia, discussed in an interview how, following the workshop, she saw the critical need to bring her own language and culture as well as that of her students front and center into her pedagogy. This approach dovetailed with the culturally sustaining pedagogical framework she already followed:

> I now take time to explain early on to students my own cultural influences and how these influences af-
> fect the way that I communicate, both verbally and nonverbally, and how I teach. We laugh at my Mid-
> western phrases, and we practice changing or translating the expressions that I might say at home with
> my family into statements that we would hear a teacher say in a professional setting. … Throughout the
> year instead of correcting language, we can refer back to how there are many correct language structures
> and decide which is the most appropriate for the presentation, lab report, or lunch conversation that
> we're having. …. Sometimes it probably seems more like an English class than Algebra! But spending
> time showing students how their language is respected, and allowing them to have the skills to analyze
> different ways of speaking and writing, creates a classroom where we celebrate what we can each bring
> to our learning environment.

An unexpected benefit of this approach was that Sasha was able to resolve some long-
standing behavioral challenges that centered on the notion of respect. 'This time spent on
code-switching has greatly reduced the number of discipline issues in my class,' she
stated. 'I used to take casual statements that students were making as rude and offensive.
It wasn't until I discussed with a student one-on-one how their words had made me feel
that I realized the intent and my judgment were completely different.' Learning about lin-
guistic microaggressions and communicative burdens, whether intentional or uninten-
tional, thus compelled Sasha to adjust her classroom practices to be more inclusive.

Along similar lines, Andre, a mid-twenties African-American educator who taught
math to Maryland public middle schoolers while he finished his college degree, ex-
plained how he often felt stereotyped based on his appearance and language.

> [In my own teaching,] I don't expect anyone to do any different based on the way they talk. But I think
> the teachers that teach me do. Like when we introduce ourselves on the first day, everybody go around
> and say your name. Most students be like, 'Hi. My name is Katherine, and I'm a communications major.'
> And they be looking like, yeah, Katherine gonna do a good job in this class. And they get to me, I'm like,
> 'Ay, what's up? I'm Dre. I'm a Black history major, and I teach math. I just be chilling.' And they be like,
> yeah, Dre not gonna do too good. And you get looked at, like, Dre—whatever.

Other participants similarly recognized, as Andre suggests, that students may not want
to change their appearance or speech for identity reasons, even if these differences can
cause stereotyping or bias from educators. James, a thirty-year-old White educator and
chair of a STEM department in a Maryland public high school, discussed how he felt
frustrated by, but nevertheless understood, one of his African-American students. 'She
is very intelligent, but she comes off as very uneducated because of the way she speaks.
And she has a rebellious attitude to a degree,' he explained. 'She understands why [she
comes across as uneducated], but she sticks with it because that's her identity, espe-
cially in a program where she's not like everybody else.'

The insight that students should not abandon their cultural and linguistic identities to
pursue STEM prepared educators to explore how to make STEM material accessible to
and engaging for students from diverse backgrounds. With the focus of our workshop
centering crucially not only on language but also on culture, our participants were able
to conceptualize STEM language and STEM learning as culturally situated. Sasha, the
Virginia algebra teacher, already sought to incorporate her predominantly African-
American students' families and thereby their cultures and communities into her teach-
ing, as part of her commitment to culturally responsive teaching. After our workshop,
however, she realized that language—how she talks to her students as well as their par-
ents and guardians—is central to this endeavor. She explained,

> As part of my goals in culturally responsive teaching, it has been vital to understand the relationship that
> my students' families have with education. Are their families excited about the newest project? Is there a
> distrust associated with school? Do students always hear about how dad isn't a 'math person' or do they
> go over homework questions with their big sister? By discussing these questions, we start to create solid
> structures for parents and teachers to collaborate. To have an audience that is truly authentic to students,

my kids help in planning family and community events, project expos, and student-led conferences—things that connect our class to their lives.

Sasha closed out her response by summing up: 'When we are mindful of how cultural differences affect student learning, we are directly showing our students that we believe that each individual student is capable of more than just doing classroom work.'

5. 'It's like a whole 'nother language': conceptualizing STEM and engaging students through a linguistic lens. Our study also investigated specific linguistic challenges the K–12 STEM educators identified as being most relevant to their own classroom contexts, particularly for African-American students, and explored their experiences with how to address them. In our workshops, participants were exposed to the idea that STEM teaching and learning—including the language of STEM—are ideologically, culturally, and linguistically situated. As we discussed how the language of a science report is different from that of a math problem set or an engineering text, the STEM educators responded eagerly with examples of how their disciplines abound with unfamiliar and difficult content area-specific terminology that students are expected to learn. Nancy, an Asian American educator in her twenties who has taught geometry primarily to tenth graders for about five years in a Virginia public high school, explained in an interview how she has adapted her teaching, because many of her students 'don't like math from the beginning' and are missing what she calls 'math language'. She described how: 'instead of saying "the sum of something," I've had to say to students "you're putting it together." It's like pulling teeth to get them to understand that *length* and *distance* of a segment, or that *calculate*, *solve for*, *and evaluate*, are the same thing.' As she put it, she and her colleagues are therefore 'often trying to teach the words and meaning before we teach the math'.

Science content posed its own challenges. In an interview, Brandon, a thirty-year-old African-American male educator, relayed his experience teaching middle-school science and robotics for six years in Maryland public schools.

> In seventh grade one of the [primary] things we teach is binomial nomenclature. That's like a whole 'nother language for them to learn. Of course, I'm not gonna ask them to learn the really complicated ones—they'll learn them if they stay interested in science—but, you know, phyla, what does that pertain to? The canines, what does that pertain to? They have hard time with it at first, because it sounds funny.

Research supports such techniques; for instance, Sutton (1992) advocates learning about 'the human voice behind the words' to acquire the language of science. Wellington and Osborne (2001:19) illustrate:

> We can explore where words have come from, i.e. their roots and origin; how longer words are made up of different parts; how some words are metaphors … , such as field, cell, circuit; how some words, such as contract, contrast, volume, have different meanings depending on where you are or where you work.

Another interviewee, Lola, is a thirty-five-year-old White woman who has taught high-school environmental science and biology classes for five years in public schools in rural Maryland. She explained how teaching science is complicated by the fact that most of her students come from low-income families where resources are limited, and her school district is severely underresourced.

> I have a few Hispanic students. I have African-American students who live in an inner city type environment, who come from about six or seven different low-income housing divisions all conglomerated together. I have [White] students who live on islands that are unable to get internet access. I have students who can get internet access but only dial-up. How do you even do your homework in a reasonable amount of time when you have dial-up? … These kids don't always come to me with those root word foundations and understanding prefixes and suffixes. In general, they just don't have a very broad vocabulary. There are things that you take for granted that they would know, like that the prefix *bio* means

life. So, sometimes when I'm trying to teach, it's like I'm speaking a foreign language. We used to kind of break up vocab and do it throughout. [Now] we spend a day or two right in the beginning of a unit doing all vocab. … If I encounter a word I don't understand, I just Google it … . For [many of my students], they don't even have that. … And even if they can just Google it, do they know what the definition means? Did they have access to those words originally?

As Lola identifies, reading for meaning is a critical issue in her classroom and a challenge for her students; as a result, she directly teaches vocabulary, as many other participants also stated. Such techniques have been found to support students' learning in STEM (Feasey 1998, Wellington & Osborne 2001, Schleppegrell 2004). But Lola also realizes that teaching vocabulary is particularly important given the economic realities of her students and her school. Students who may not have the skills or resources to 'just Google' the definition of a word should be taught what it means. As Sonya, a mid-thirties White female math teacher in a public Maryland high school, similarly noted during the focus group:

If you use synonyms, if you use a more complicated word, that's what a lot of students don't know. And it's a problem because a lot of [teachers] expect students to know those words, and they won't explain them when it's on a test. They say things like, 'You should know what that word means.' But if you don't explain it, how are they going to learn?

During the focus group, Ashley, a mid-twenties White high-school biology educator in Maryland public schools, described a culturally related vocabulary challenge that occurred in her fellow teacher's science class, which enrolled a high proportion of African-American students:

There was an incident on a final exam last semester. The students were supposed to learn categories of different phyla. On one question, the teacher made a substitution. Instead of the word *fungus*, she used the word *truffle*, which is a fungus. She just wanted to change up the way the problem was written to make it more interesting. Part way through the final exam, a large number of students asked, 'Are we supposed to know these words?' Some of them were lengthy words, like cyanobacteria, and yes, that one you're supposed to have learned. But a lot of students were like, 'What's a truffle?' And that's a test question worth 20 points. You could lose 20 points because you don't know what truffle is. Science teachers should be aware that a word can make a difference, and you might not be getting a good gauge of what students know about science. It might be a really obscure word to certain students, and the whole question is based on that.

As Ashley recognized, it was not only the unfamiliar word that her colleague used but also her cultural and social assumptions that became barriers to accurately assessing these students. Understanding commonalities and differences across students' backgrounds and a teacher's own can thus give greater insight into what scaffolding students may need to learn STEM content—a crucial endeavor since, when culturally relevant material is incorporated, student engagement and student learning are found to increase (Delpit 2012, Eglash et al. 2013).

Corinne, a White woman in her twenties who teaches geometry in an independent high school in Maryland, further discussed how she used one-on-one discussion to help students work through psychological and linguistic barriers to test performance. She referred to the difficulty that math word problems on standardized tests can elicit for many of her predominantly African-American students, particularly in the form of emotional responses, due to linguistic and cultural challenges. 'I can give them a basic algebra problem, and they can understand that because it's the math they've always seen,' she explained. 'But the second I give them a big word problem, they become completely overwhelmed … , and they shut down. [It's] immediate. So getting them to just try it and apply reading skills is the struggle before even attempting the problem.' The psychological factors that Corinne identified relate to stereotype threat, which, as Steele

and Aronson (1995) identified, can severely affect African-American test takers. More-over, testing situations that include a verbal component can cause African-American students to become hesitant and taciturn (Labov 1972). To help students overcome these issues, Corinne makes time to meet with them after class: 'When I notice they're struggling, I'll tell them stay today. Work one-on-one with me or work with a tutor or ask me questions and let me try to rephrase it in a way that you might grasp. One-on-one help works very well.'

Allison, a White educator in her thirties who teaches fifth grade in a Virginia public school, similarly discussed in an interview one of her African-American male students, who often struggled emotionally when he could not understand the wording on tests.

> He was excellent in math, I mean excellent, but he didn't believe it. … So he'd be working on a math test, and he would get to a word problem that just threw him for a loop, and he would literally like, GRUNT—put his pencil down, grunt, put his head down, make noise, move around. I'd say, 'Come on, come to me. Read it out loud to me.' And HALFWAY THROUGH he'd take a deep breath and go, 'Ohhh! I thought it said blah-blah-blah, but it really said blah-blah-blah.' When they get to that frustration point, [you have to] let them take a breath, let them verbalize what they're going through.

Allison calls attention to the need for teacher support for students who may need additional scaffolding or different strategies to overcome hurdles, from unfamiliar wording to stereotype threat. Other participants also mentioned helping students rephrase questions and 'explain what they are thinking out loud', as Nancy put it, as a strategy for addressing barriers to test performance. With respect to math, Street (2005:136–40) similarly supports the use of techniques like backchanneling and framing to encourage active learning (see also Wellington & Osborne 2001:83).

Our educator participants also found that one equity solution was to pay attention to wording—not only on standardized assessments of external origin, but also on their own tests. Sheila, an African-American woman in her thirties who teaches middle-school math in a Maryland public school, reported in an interview how powerful it was to learn that her wording could affect students.

> Structuring questions, and how subtle changes in the wording of those questions could make an impact for some students … it changed how I thought about making the biggest impact with my students. Maybe I was not being as effective. Maybe there were things that I could change with how I presented questions, how I asked questions or gave directions that would make my message clearer. With mathematics we all use language, whether it's in the directions we give or the handouts we use.

The issue of question wording particularly resonated with Dave, a White male high-school science educator in his forties, who taught in Virginia. After completing his interview, he emailed us to further share how, based on this knowledge, he decided to revise his assessments. He discussed how his habit of making what he once thought were 'fun and funny' test questions might increase their difficulty for students who did not share his culturally situated knowledge:

> After our extended unit on beach ecology, my marine science classes would take a test that I had written entirely in 'surfer lingo'. For instance [quoting directly from a test]: 'Okay, now focus, dude, focus! Suppose you're straddlin' your surfboard out past the breakers. Some sweet head-high ground swell is just arriving from a distant cyclone, and you find yourself bobbing up and down with a frequency of 0.125 Hz. At what depth did this excellent wave train first begin to "feel" the bottom, dude? At that moment, how righteously fast was it moving along? State units and circle final answers, will ya, dude?!' It was supposed to be fun and funny, and many students seemed jazzed by it, but in retrospect it probably wasn't a good idea. And then—I'm embarrassed to admit it—there was the test that I wrote in pseudo-Shakespearean English. … There were 'Shorteth Answereth' questions like [sharing directly from a test]: 'Zounds! The vengeful gods have cast thee into the darkest depths of the sea, and condemn'd thee to live out thy days well beneath the sunlit photic zone. Luckily, Neptune hath agreed to grant thee 3

> Wishes for adaptations to help thee survive. Name ye thy wishes, three, and explaineth.' Guess I'll have to trash that too, for *everyone's* sake, regardless of dialect.

Much of what our present study indicates is that we must get STEM teachers into the conversation about general academic language, which is at the heart of all disciplines, including STEM. Indeed, many of our teacher participants shared this insight directly. But challenges that culturally and linguistically diverse students routinely face are also more than just issues related to jargon or academic writing. A complex relationship between culture and language deeply affects teaching and learning in STEM classrooms. We must make sure that STEM educators are part of these broader conversations so that the issue of language and learning in STEM is not left to either just linguists or just language arts educators. Along these lines, Rebecca, a White woman in her mid-twenties who teaches first grade in a predominantly African-American public elementary school in Virginia, described an ambition to improve her teaching by respecting and preserving her students' communicative diversity. In an interview, she described the detriment of viewing 'students who have non-standard language variation as a deficit. Like, "He doesn't know what *this* means," "She doesn't know what *that* means" '. Instead, she pointed out the power of valuing students' cultural and linguistic differences:

> What's been huge for me is providing my students the time to, you know, 'Show me what you know. What would you call this?' Especially with science and math terms, because [my students] DO have such rich background knowledge, but it can be hidden behind ME not knowing.

In this approach, educators hold high academic expectations and rigor while creating a classroom climate that values linguistic and cultural diversity. Students learn school language and STEM language without having their linguistic and cultural identities devalued in the process. Language and culture are worthy of specific inquiry in STEM classrooms, and this inquiry can be a place of common ground for engaging educators and students so that learning can flourish.

6. CONCLUSION. Our findings illustrate the complex educational and ideological contexts that K–12 STEM educators face—including the demands that the education system puts on them as professionals. To date, sociolinguistic literature has been fairly general as to the question of how to respect students' language and culture within STEM educational settings. Our study delved deeply into this question. Our findings demonstrate that linguistic messages to K–12 STEM educators, where such information is usually scant, need to be tailored—not only to educators' respective student populations but also to their content areas and local pedagogical contexts. Our findings also support the efficacy of in-person, collaborative, and inquiry-centered professional-development workshops as a model for linguistic outreach and engagement with K–12 educators—in general and in STEM. Through the vehicle of professional-development workshops, we developed the sustained relationships with educators that were necessary for them to integrate linguistic information into their teaching, and for us as linguists to understand their local school and classroom contexts and how linguistic information fits into the equation. Rather than just promoting inclusive yet artificial, static concepts, researchers who are eager to promote awareness of and attention to cultural and linguistic diversity in educational settings must carefully consider and explain these dynamic situations of profession and professional identities within localized contexts and communities. As a pathway for future work in this area, we therefore lay out five explicit steps that recommend how to carry forward this line of research.

Our first two steps are geared toward STEM educators, seeking to further integrate sociolinguistic information into their classrooms and schools.

(1) Partner with local linguists to help develop the tailored nuances that sociolinguistic insights bring to STEM education. Because linguistics is at the intersections of the humanities, the social sciences, and the natural sciences, linguistics can be a good way to show how disciplines and educational approaches are interrelated. Through a linguistic approach, we can demonstrate why language IS culture—and why they both matter in STEM learning environments.

(2) Remember that identity and culture matter, not just achievement. Talk to your educator colleagues about language and culture, and emphasize the notion that students must see and hear themselves as scientists. Students who are interested in STEM may still 'opt out'—a means of implementing a risk-management model—when STEM environments are hostile (see e.g. Beasley 2011). Using linguistic insight to invite students into the culture of science and encouraging students and educators to think and work critically to change damaging messages and cultural norms is part of promoting student achievement.

Our final three steps are geared toward sociolinguists who do educational engagement work, including but not limited to working with STEM educators.

(3) When doing teacher training, it is not necessary to start with the most controversial topics or work with the most 'resistant' educators in your first workshop. Rather, take time to develop your materials and understanding of educator challenges and narratives. Get to know educators and talk to them about language and their linguistic insights. Ask what questions they have and understand how linguistic information might be able to add to the conversation before feeling like you have to directly address such issues, particularly with teachers who seem resistant (see also Mallinson & Charity Hudley 2018).

(4) Realize that African-Americans in schools are still embedded within a larger and largely structural White culture. Discussion that initially and directly focuses on African-Americans may not reach all educators because of racism in our society. Rather, an approach that builds cultural empathy from the educators' point of view may be a more effective segue. All languages vary, so using that information to help educators remember that it is a good thing to be multilingual and multivarietal—coupled with helping educators think about ways that they can promote learning across cultures—is a good first step to having more challenging conversations about race, inequality, and justice.

(5) Demonstrate and appreciate the types of conversations that participants may have during the workshops so they can anticipate different language streams. Such narratives are nuanced, which means that the full complexity of what the educators are saying must be directly responded to. Simplistic notions such as 'all languages matter' will not help with actual classroom praxis, which is localized and specific. Research in this area is still new, so educators will have more questions than we have answers for. Establishing a sense that we are all researchers in this together can help mitigate that understandable frustration.

K–12 educators from different fields need to speak the same pedagogical language in order to foster effective interdisciplinary collaborations and partnerships. Our study is a step toward 'getting everyone in the room', as our participant Rebecca put it. The educators in our study learned that STEM teaching and learning is not context-free or universal; rather, structural, sociocultural, and ideological factors overlap and interact to

affect student achievement. Beyond simply learning information about linguistic challenges that students may face, our participants also drew upon their own experiences as well as the materials we presented to them. They learned how, with knowledge about language variation in STEM contexts, they can enhance how they approach teaching culturally and linguistically diverse students, particularly African-American students. Insights gleaned from the interviews and focus groups reveal the utility of culturally and linguistically sustaining pedagogical approaches that are specifically geared to reach African-American students. As educators become better equipped to serve students from groups such as African-Americans that have been historically underrepresented in STEM, and as underrepresented students are increasingly able to see and also to hear themselves as scientists, STEM fields become less exclusive and exclusionary domains. This finding is important also for linguists who aim to do outreach and engagement with K–12 students: it is crucial to assist students not only in learning academic material and information, but also in developing their own linguistic agency and finding their own voice (Charity Hudley & Mallinson 2014).

Our study represents a starting point; much more research is needed on the specific manifestations of how structural linguistic factors endemic to STEM academic culture interact with linguistic bias and discrimination to impede educational opportunities for African-American students and students from other underrepresented groups. An inherent limitation of our research is its dependence on the self-reported insights of educators who were already interested enough in culturally and linguistically sustaining STEM education to sign up for a professional-development workshop on the topic. Accordingly, future research that includes observational data and additional input from students and educators is needed to further interpret how information on language variation affects teaching and learning in a variety of pedagogical settings. For instance, researchers need to continue to explore how issues such as stereotype threat, macroaggressions, and microaggressions manifest as specific linguistic acts in STEM at all educational levels, not just K–12. Much more research is also needed on what culturally and linguistically sustaining instructional techniques look like and how educators apply them. Some specific pedagogical strategies are referenced throughout this article, but more systematic inquiry is needed to examine how educators can develop and implement a repertoire of strategies to build on the cultural and linguistic backgrounds of their students, particularly their African-American students, as rich resources for learning. Analyzing how educators do the day-to-day work of creating culturally and linguistically sustaining classroom cultures requires that scholars continue to build sustained, long-term relationships with educators, follow their teaching practices, and study the effects. Information from greater numbers of educators and from a wider set of classrooms and schools would also further reveal broader insights into how an understanding of culturally and linguistically sustaining pedagogy can benefit STEM teaching and learning. Finally, models of how to disseminate such information to other STEM educators, administrators, and students are also necessary and will be able to inform school-university partnerships and improve curriculum, instruction, and policy.

Language is a central component of culturally sustaining teaching and of inclusive education, in all content areas, including STEM. Content and information are delivered through communication; educators' beliefs about and expectations for their students, as well as students' expectations for their educators and for the learning process, are also articulated through language. With information and knowledge about language variation, educators can develop robust cultural and linguistic competencies and tools that equip and empower them to do the culturally and linguistically sustaining teaching that

is fundamental to the persistence and success of African-American and other under-served students in STEM. Through carefully designed outreach and engagement part-nerships with these educators, linguists have a critical role to play in advancing equity in STEM education.

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