Leveraging the Cultural Practices of Science for Making Classroom Discourse Accessible to Emerging Bilingual Students

Enrique Suárez and Valerie Otero, University of Colorado – Boulder, 249 UCB, Boulder, Colorado, 80309
enrique.suarez@colorado.edu, valerie.otero@colorado.edu

Abstract: Despite extensive research and national reports that call for students' engagement in scientific practices, these strategies continue to be virtually absent in classrooms throughout the U.S. Thus, the question of how students who are learning English as a second language fare in these environments is virtually unanswered. This study presents results from an investigation on 3rd grade emerging bilingual students' participation in a physics lesson on sound production. We focus on the changes in participation as such changes pertain to scientific practices of argumentation, modeling, and experiential, imaginative, and mechanistic reasoning strategies. Drawing from students' discourse and gestures, conjectures are made about scientific practices being particularly well suited for fostering productive disciplinary engagement for emerging bilingual students.

Problem

There is a large number of students in the educational system who are learning English as a second language, with a small number of teachers trained to meet their language needs. Because learning environments are predominantly designed to accommodate English as the sole language of communication and instruction, emerging bilingual students are often not fully included in classroom activities. Forecasted shifts in the U.S. population predict an increase in the number of emerging bilingual students in schools (Kindler, 2002), which means an even greater number of students run the risk of being excluded from classroom activities. / Because of the emphasis on acquiring English as a second language, this group is often referred to as English Language Learners (ELLs), a label defines students solely based on language acquisition (Escamilla and Hopewell, 2010). Since we want to highlight the range of resources they bring to the classroom, throughout this study we use the term *Emerging Bilingual Students* to refer to these students.

With most school efforts focusing on increasing emerging bilingual students' fluency in English, science has lost priority in the elementary curriculum, which we see as a missed learning opportunity. Pressures to increase the language fluency of emerging bilingual students has led to a nationwide trend of teachers and administrators increasing the amount of time spent on regularly tested subjects such as mathematics and language arts. Consequently, there has been a significant decrease in classroom time devoted to science (McMurrer, 2008). However, science could provide opportunities for students to use language as a tool for communicating shared observations about the natural world and making evidence-supported claims. Thus, decreasing classroom science time may be counterproductive to students' development of language. We argue that a science classroom centered on scientific practices is particularly well suited for including emerging bilingual students. If the learning environment has certain conditions, we can tap into this certain thing students have, which can lead them to engage and participate in activities. By capitalizing on students' natural curiosity and desire to understand phenomena, learning environments can support students in engaging with peers in discussions about shared observations and questions that are meaningful to them. By participating in these kinds of conversation, students can simultaneously improve their English fluency and understanding of the physical world.

The creation and adoption of the Next Generation Science Standards (NGSS) in K-12 schools (Committee on Conceptual Framework for the New K-12 Science Education Standards, 2012) promises changes in the landscape of science education, prompting more research for understanding how students engage with disciplinary practices. As more states adopt NGSS, there is a push for integrating scientific practices such as model building, mechanistic reasoning, communication, and argumentation into classroom activities. And while there have been valuable efforts to understand the role language plays when emerging bilingual students learn science (Rosebery, Ogonowski, DiSchino, Warren, 2010; Suárez and Otero, 2013; Suárez and Otero, in press; Warren, Ballenger, Ogonowski, Rosebery, Hudicourt-Barnes, 2001; Warren, Ogonowski, Pothier, 2005), it is still not yet clear how to increase the participation of emerging bilingual students in science classroom activities. In this study we explore the hypothesis that science, physics in particular, is particularly well-suited for increasing the participation of emerging bilingual students in negotiating meaning and participating in class. We analyze a group of 3rd grade emerging bilingual students as they make sense of the sound produced by a guitar-like object. First, we present an analysis of how a student's proposed terminology for describing a physical phenomenon spread across the class and was adopted as a sort of "academic language" later used to talk about mechanisms on the basis of observations. Second, we analyze the participation and behaviors of one student who increasingly became more engaged as the discussion progressed. This work is relevant both practically and theoretically. Theoretically, it contributes to conceptualiszing how various scientific practices and academic language are mediated by students' everyday language and experiences. Practically, findings lead to concrete recommendations for how various features of a learning environment could increase participation of emerging bilingual students.

Theoretical Background and Literature Review

We view learning as a social practice (Rogoff, 1994; Wenger, 1998) and assume that students' development of conceptual understanding and language skills is co-constructed through social interactions. Therefore, learning environments that favor English as the only language for teaching and communicating creates a distinct set of challenges for emerging bilingual students. Specifically, students' language skills and discourse practices are often different than the ones valued and used in school settings, an incongruence that often leads to the disfranchisement of students and hinder learning (Warren *et al.*, 2001). In thinking about designing learning environments that bridge this language barrier, we propose that physics has a clear advantage over other subjects because experimentation typically involves the presence of tangible objects and shared observations. Moreover, scientific practices involve supporting and promoting student participation through reasoning, argumentation, and sharing ideas about observations of phenomena, all of which can be accessible to students with different levels of English fluency.

Researchers have proposed Productive Disciplinary Engagement (Engle & Conant, 2002) as a construct for describing active student participation. Specifically, this type of engagement is defined as one in which students spontaneously participate, substantially contribute, and attend to each others' ideas in a way that resembles disciplinary discourse practices and furthers intellectual progress. Four measures have been suggested to evaluate if a learning environment can foster this type of engagement. First, teachers should encourage students to problematize the content through questions, proposals, and challenges. Second, it is important for "students to be authors and producers of knowledge … rather than mere consumers" (Engle & Conant, 2002; p. 404). Third, students should be held accountable, particularly by how their work is responsive to what community insiders and outsiders have established. Finally, it is necessary for students to have relevant intellectual and/or material resources to aide sense-making (Engle & Conant, 2002). While this is not the only framework that describes disciplinary engagement, we chose it because of how well the four principles align with disciplinary practice, especially authorship and accountability to the local and disciplinary communities.

We see almost a one-to-one correspondence between the four principles proposed by Engle and Conant (2002) and what we would expect to find in a learning environment based on inductive reasoning. To make the connection apparent, here we define scientific induction. The process of scientific induction ideally consists of observing physical phenomena and collecting evidence, followed by testing and postulating generally applicable principles supported by the data. Subsequently, these evidence-based claims are presented to the scientific community and subjected to the peer review process. The community ultimately (though not usually directly) arrives at consensus regarding inclusion of these principles in the larger corpus of knowledge.

Classrooms that espouse the scientific inductive process almost effortlessly meet the criteria described above for productive disciplinary engagement and promote meaning-making during activities. In these learning environments students problematize content through their observations and are authors of the evidence-based claims; these abstractions of are submitted to, and evaluated by, other students in the community. This framing aligns with Vygotsky's theory of concept formation (Vygotsky, 1962), which proposes learners move between two types of spaces: informal spaces that are populated with everyday experiences and interactions with the physical world; and academic spaces that house formal knowledge made available and validated by disciplinary communities. During the process of concept formation learners develop conceptual understanding through grounding academic concepts in everyday experiences, while leveraging these particular instances for deriving generalizable, academic concepts (Otero and Nathan, 2008).

Even though structuring classroom science activities on principles of PDE has great potential for increasing accessibility, it is important to consider what features of the learning environment are effective in supporting the inclusion and participation of emerging bilingual students. Some argue that what is needed is the creation of hybrid spaces (Gutierrez, Baquedano-López, Turner, 1997) where students can recruit everyday language and communication practices when sharing ideas associated with formal, academic terminology and classroom norms. These emergent *third spaces* integrate everyday space (counterscript) and academic space (official script), "creating the potential for authentic interaction and learning to occur" (Gutierrez *et al.*, p. 372). These third spaces allow for the trying out of new, academic terms through the negotiation of meaning by deploying one's own, everyday language and discourse practices. Gutierrez and her collaborators (1997) suggest that literacy development is related to students' deployment of everyday language in the service of testing of formal literacy practices. Through this bi-directional process, students construct and negotiate meaning. We argue that the same process is possible in science.

Framing students as active participants in the meaning negotiation process extends to the conceptualization of language development. Based on the work by Razfar and colleagues (Razfar, Licón Khisty, Chval, 2010), we adopt a sociocultural perspective in which language development and construction of knowledge arises from interactions within classrooms. From this viewpoint, a sociocultural model of language development redefines “language as a mediational tool for learning rather than the object of learning and instruction” (p. 214). Razfar et al., (2010) prompt us to think about language development as concrete steps students take towards “the use of any word to signal an object in a decontextualized manner” (p. 201) and abstraction, which can only be achieved through situated meaning-making. This has significant implications for how teachers structure learning environments and activities for students to engage with. Particularly, the fundamental question for designing and organizing learning environments should be “how will students use language to reach the learning goals?”, rather than “what language do we expect students to acquire?” This position differs significantly from *second language acquisition* models, which construct language as an external device that needs to be acquired by the learner, instead of a meditational tool that is socially and iteratively constructed through interactions. Finally, sociocultural models avoid the pitfall of positioning learners as having a deficit that needs to be addressed by the teacher. Instead, it positions students as capable of learners whose development depends on the participation on multiple types of meaning making activities.

Building on scientific induction, models of student engagement, and models of English language development, we expand our initial conjecture. We hypothesize that science is particularly suited for creating hybrid spaces that provide opportunities for emerging bilingual students to become the authors and evaluators of evidence-based claims generated by shared, tangible experiences, furthering conceptual understanding. Simultaneously, science activities that promote the interaction between students’ everyday language and academic language can aide the processes of English language development, as well as in the construction of scientific language and meaning. In this study we address the following general question: *what role do everyday and academic language play when emerging bilingual students engage in making sense of the physical world?* In order to address this question, we analyze a five-week unit on sound, in which third grade emerging bilingual students establish a connection between physical properties of strings (length, tension, and frequency of vibration) and the characteristics of the sounds produced by them (pitch and volume).

Research Design and Procedure

Thirteen third grade students participated in this study, all enrolled in a large K-8 urban public school; the names of the participants are pseudonyms. The school ran a “Mainstream” program for monolingual English speakers and students who were considered “proficient,” and a Sheltered English Immersion Program (SEIP) for students who were classified as English language learners by the district. Each grade level was divided into two mainstream classrooms and two SEIP classrooms. The two SEIP classrooms were organized according to the school’s determination of students’ level of English proficiency: *beginner*, *intermediate*, and *transitioning* (to mainstream classrooms). Within the school, 66% of students were classified as ELLs, 76% qualified for Free and Reduced Lunch, 45% of students identified as Hispanic, 31% as White, 13% as Asian, and 9% as African American.

Data were collected from a third grade, SEIP classroom with a mixture of students identified as having beginner and intermediate proficiency. Students represented nine different first languages and students and their families came from eleven different countries including Haiti, Albania, Brazil, El Salvador, and Nepal. Students’ length of residence in the country ranged from US-born, to arriving up to three months before recording the lesson we present below. The episode we analyzed for this paper was part of a five-session unit on Sound. Based on the state’s curricular and language requirements, the teacher and first author planned the unit with the intent of highlighting the vibratory nature of sound and the relation between vibrations and sound characteristics (e.g., pitch and volume). We focused our analysis on the third session, “Making sense of a guitar,” since it seemed to have the richest discussion by students investigating the sounds produced by a guitar-like instrument. Specifically, we selected excerpts that showcased a shift in students’ engagement, as well as sophisticated reasoning.

In an attempt to capture the complexities of ideas and interactions in the classroom, video recordings on four of the sessions described above were collected. In addition to the video, the first author wrote journal entries describing what had taken place during each session, and took notes during the debriefing meetings with the teacher. Videos were transcribed and coded according to the four principles for productive disciplinary engagement proposed by Engle and Conant (2002): (1) problematizing observed phenomenon (further broken down below), (2) display of authorship of ideas, (3) accountability to their local community, and (4) use of material resources. We identified two categories of problematizing observed phenomena that pertained to the sound production mechanisms students referred to when exploring the guitar: *physical features of the producer of sound* (size or length of the string, tension on the string, frequency at which strings were perceived to vibrate) and the *characteristics of the sound produced* (differentiate between low and high pitches). These codes for problematizing observed phenomena, which attend to mechanistic reasoning (Russ, Scherr, Hammer, Mikeska, 2008), were further investigated in terms of how, and for what purposes, students used everyday and academic language in the service of constructing explanations. Using an inductive coding approach we identified a wide range of uses of language by coding both language and gestures.

This study explores the following research question *what role do everyday and academic language play when emerging bilingual students are making sense of the physical world?* Specifically: (i) what features of a classroom based on scientific induction foster engagement of emerging bilingual students? and (ii) how can this engagement support students' reasoning about mechanisms that drive observable phenomena?

Findings and Analysis

We focus on student participation throughout a discussion on sound to exemplify how attending to physical phenomena can provide emerging bilingual students access to classroom discourse. In this particular episode, students presented their ideas on how the physical properties of the strings of a guitar-like object affected the type of sound produced. As suggested below, students' use of familiar language to describe the different mechanisms that drive differences in pitch seemed to have been instrumental in making discussions accessible to students. Through leveraging everyday terminology, which was sanctioned by students through its usage, students contributed to the group's efforts of making sense of the underlying mechanisms connecting the physical properties of strings and the pitch of the sounds produced.

For this lesson, the students all sat on the carpet in a circle. The session began when the researcher (first author) held the guitar-like object and asked students what they made of it. Gustavo, a Brazilian-American student who was always ready to offer his thinking, stood up and approached the instrument, claiming he knew what it would sound like. The researcher handed the instrument to Gustavo and, while plucking each of the four strings, he aurally imitated the sound he heard: "tick tick, tack tack, tock tock, tuck tuck." Gustavo handed the guitar back to the researcher, and the following exchange ensued:

22.	Researcher:	Can you - can you tell us again, Gustavo? The sound, the sound. Just make the sound again.
23.	Researcher:	With your mouth. With your mouth.
24.	Gustavo:	tick tick, tack tack, tock tock.
25.	Researcher:	OK, and which ones makes ting ting? This one makes ting ting?
26.	Gustavo:	No, the first one.
27.	Researcher:	The first one makes ting ting? And the second one makes...
28.	Gustavo:	tang tang.
29.	Researcher:	And the third one?
30.	Gustavo:	tong tong.

When asked to describe what he heard when plucking the strings, Gustavo offered that the first and shortest guitar string sounded ting ting; the second guitar string sounded tang tang; the third guitar string sounded tong tong; and the fourth and longest guitar string "doesn't make any noise." The group first received this contribution with laughter. This was the first time that any of the students had characterized sound in these terms. In preceding sessions, the teacher used academic terminology when describing sounds produced by vibrations and students were familiar with the use of academic terminology. Soon after Gustavo's remarks, other students appropriated the labels (ting, tang, tong) when talking about the sounds produced by the strings, and the use of "ting tang tong" increased as the discussion progressed. We see the increased and continued use of "ting tang tong" in reference to the sounds made by the instrument as evidence that this everyday language was becoming sanctioned by students, and increasingly became the "formal" class vocabulary for referring to the various strings on the instrument.

Students took up the terms "ting tang tong" and appropriated this language to expand on and communicate scientific ideas. In a sense, these labels became *linguistic footholds* due to their onomatopoeic nature, rooted in students' observations, in conjunction with their connection to the tangible object that could be held, touched, and played by any student in the group. We claim that this invented and/or informal terminology, together with the presence of a tangible object, and the opportunity to negotiate meaning about this observed phenomenon increased the discussion's accessibility. We argue that this connection to students' everyday lives and language fostered students' practice of, and confidence in, authoring explanatory ideas, given students' familiarity with and expertise on sound and musical instruments. Often, students' innate ability and desire of making sense of the world around them is overlooked, missing an opportunity for creating a connection between their everyday lives and science.

The intersection between the formal science (script) and the informal everyday language and experiences (counterscript) is where we see the potential for the emergence of third spaces. In the particular case of the discussion on the guitar, we observed three critical elements leading to the emergence of a third space: (1) a participant, Gustavo, invented these labels, (2) the group appropriated and used these terms frequently, and (3) the teacher allowed this type of (relatively informal) talk to continue. We argue that a third space was generated and it created opportunities for students to participate. The teacher did not correct Gustavo's language or overrode these labels with the formal academic terminology. Therefore, space was provided for students to express themselves by integrating everyday, onomatopoeic terms, their experiences, the instrument, and the space to embark on a discussion using the scientific practice of mechanistic reasoning to negotiate meaning of the causes of sound. To further support the explanatory power of the notion of linguistic footholds and third space, we focus the rest of this section on Gyorgy, a Hungarian student who had been in the U.S. for a little over six months by the time this episode was recorded.

Before the start of the discussion, Heidi, the classroom teacher, showed students the guitar she had built. While she was talking, we saw Gyorgy, a typically shy, reserved child, in the background moving his hands and arms as if he were strumming a guitar, and then playing a piano, then tooting a trumpet, and playing the drums. Although his gestures were obvious after watching the video recording several times, they were relatively disguised in the background with respect to the circle of students in the classroom discussion. Gyorgy sat back in the circle, with his back hunched and his shoulders curled in and forward. While Gustavo was presenting his ideas about how each string sounded, Gyorgy sat facing Gustavo and was completely quiet. When Gustavo took the guitar from the center of the circle back with him to his seat on the rug, Gyorgy was within reaching distance and made a couple of quiet attempts to touch and strum the strings. He still did not contribute to the conversation, although his gesturing suggests he must have had previous experience with music. Despite demonstrating knowledge and enthusiasm about musical instruments, Gyorgy did not voice his experience-based ideas. But his silence was about to be broken.

Minutes after "ting tang tong" was introduced, Gyorgy watched Gustavo scratching his chin and raising his hand to ask for a turn to speak. Gyorgy then appeared to mimic Gustavos's behaviors by scratching his chin and almost raising his hand (in a non-exaggerated, somewhat timid way). It seemed that he also wanted to contribute to the conversation and was impressed by the ease with which Gustavo did so. When called on by the teacher, Gyorgy's facial expression showed what could be perceived as anxiety over having to speak up, and his body slouched forward and kind of curled up as he began shrinking backward away from the circle. When the researcher asked Gyrogy if he would like to try explaining his thinking, Gustavo immediately shot his hand up, to which the teachers replied by asking him to let Gyorgy try. Once again, Gyorgy's face appeared anxious, but this time he looked down, stared at the floor, and shook his head and timidly gestured, "no." Heidi, intervened:

70. Heidi: Gyorgy, do you want him to repeat the question? Or do you understand the question?
71. Heidi: Use your English. You're doing great. You've been doing really great.
72. Gyorgy: No, no.
73. Heidi: Yes, yes, you have.

Once again, Gyorgy looked down, avoiding eye contact with Heidi, and remained in the far edge of the circle and away from the guitar for about five seconds. The teacher continued to wait. After that wait time Gyorgy took a deep breath and said quietly at first, "I have a question," and approached the center of the circle where the guitar sat on the floor. Gyorgy moved forward, kneeled and looked at the guitar from above, paused for a five seconds, and said:

76. Gyorgy: This [first string], ting ting. And this, tang tang [second string]. And this one [third string], Gustavo?
77. Gustavo: tong tong.
78. Gyorgy: Because this [first string] not really – (pointing with to the first and third strings)
79. Gustavo: Short.
80. Gyorgy: And this [first string] small, and big (pointing to second string), and bigger (pointing to third string).
81. Researcher: Small, big, and bigger? So, small is -
82. (Gustavo: Medium.)
83. Researcher: ting ting (Gyorgy shakes head in approval)? And medium is tang tang (Gyorgy shakes head in approval)? And bigger is tong tong (Gyorgy shakes head in approval)?
84. Gustavo: Can I say why?
85. Heidi: And why?
86. Researcher: Yeah. Why do you think is that, Gyorgy?
(20 seconds of silence)
90. Researcher: Are you done, Gyorgy? Do you want to say anything else?
91. Gyorgy: I don't know what to say, because - I'm done

92. Researcher: OK. Thank you, Gyorgy. That was really good. Thank you.
93. Heidi: Nice job, Gyorgy
…
104. Researcher: Gisela, do you wanna try? What do you think?
105. Gisela: Because, when you like "eeeeeeee," and it goes high, and that (first) string goes high. And when we go "aaaaaaaa," that (third) string goes low.
106. Researcher: OK. So, that's why we say it's high pitched and low pitched? It sounds very similar? OK.
107. Gustavo: I know why.
(Gyorgy raises his hand)
108. Researcher: Ok. Gyorgy?
109. Gyorgy: Is because this [first string] is very fast, is very fast; and this [second string] not very fast; and this [third string] is slow.
110. Researcher: Oh.
111. Gyorgy: See? This [first string] very fast - (Gisela: Like the ruler.) and this [first string] hard. And this [second string] not hard. And this [third string], this easy.

After being encouraged by Heidi, Gyorgy's demeanor changed: he approached the instrument and presented his ideas to the group. He no longer appeared shy or anxious, and instead lunged himself forward almost completely dominating the space around the guitar. Additionally, when offering an explanation, Gyorgy appeared comfortable pointing to the specific string he was thinking about, while looking at his peers and teachers. Gyorgy seemed to have accepted the invitation of becoming part of the discussion, appearing in complete control of the situation. It is important to remark that, this exchange was the first time the onomatopoeic labels were used by a student other than Gustavo, and marked the start of a formalization process. As the discussion progressed, Gyorgy became more vocal and shared his ideas with more ease and confidence.

The excerpt above also shows Gyorgy engaged in the scientific practice of mechanistic reasoning. Particularly, he pointed out possible mechanisms that produced the different sounds, "this (first string), ting ting, and this (second string), tong tong. And (first string) small, and (second string), big and (third string) bigger" (lines 76 and 80). Engaging in mechanistic reasoning (Russ et al., 2008) is one of the fundamental practices scientists engage in when developing and evaluating explanatory models, and should be central to the teaching and learning of science. Moreover, Gyorgy used the labels Gustavo had invented and also checked with the author to see if he was using the correct invented terminology (line 76). We interpret this remark as denoting the connection Gyorgy was making between the physical features of the strings and the characteristic of the sounds produced. Specifically, here we see that he, like Gustavo, used the onomatopoeia to talk about *the relationship* between length and pitch, e.g., "the ting ting string is small." The second connection Gyorgy made was between the frequency at which the string vibrated and pitch, when trying to understand why the short string sounded "eeeeee," "[first string] is very fast" (line 109). He quickly added that the first string was also hard (line 111), which we interpret as Gyorgy relating the tension he felt on the string and the sound's pitch. We argue that implicit in this discussion was Gyorgy's experience with instruments and his innate drive to make sense of the world around him.

Gyorgy's participation throughout the discussion illustrates the emergence and maintenance of a third space that allowed students to leverage elements of their everyday language and experiences in service of exploring physical mechanistic processes. Specifically, the creation and sanctioning of linguistic footholds made the discussion about the guitar accessible to Gyorgy. We argue that for him "ting tang tong" served as the foundation through which he would externalize his thinking, and from which he would continue to expand his understanding of sound. These experiential labels had great information about the system codified into them, which in this case is the pitch of the sound produced by each of the string. Therefore, when referring to the "tong tong" string, for example, students are talking about a particular string within the guitar (position) and their expectation of sound characteristic (pitch). Moreover, we claim that the creation of onomatopoeic labels that derive from observations signaled students establishing a bidirectional connection between experiences and abstract ideas (Vygotsky, 1962). The invention of a label is a step towards exteriorizing and objectifying ideas, which plays an important role in constructing disciplinary knowledge. Moreover, the onomatopoeic nature of "ting tang tong" reified the shared experience so that, even though it was no longer present, students could now elaborate with abstract and mechanistic reasoning. In general, we recognized that students often used non-academic language when describing their ideas about sound, which eventually became sanctioned by the rest of the group through its widespread use.

Additionally [in addition to?] to the richness embedded in and symbolized by the linguistic footholds, we assert that they fostered Gyorgy's *productive disciplinary engagement* (Engle & Conant, 2002). The labels seemed to have served the important function of helping Gyorgy publicly problematize the physical processes in the guitar, by on the causal mechanisms that connected the physical properties of the string and the pitch of the sound he heard. Rather than just stating the fact that the first string was shorter, Gyorgy tried to make an explicit connection between the length, tension, and vibration frequency of the string and the pitch of the sound he heard. And we surmise that his reasoning about mechanisms contributed to the group's understanding of the guitar, given that he was trying to establish a causal link between the cause (length) and the effect (pitch) of sound production.

Once Gyorgy's participation in authoring ideas increased, it appeared as if his confidence and position also changed. At first, despite demonstrating knowledge about musical instruments, he refrained from making contributions to the conversation. Once the teacher called on and encouraged Gyorgy, he appropriated the vocabulary created by Gustavo and used it for communicating his thinking. Subsequent remarks seemed to be related to his own thought process, rather than revoicing other students' comments. Again, we see this process as evidence that Gyorgy became an author of ideas in this space, rather than a consumer, while remaining accountable to the local community by continuing to use formalized vocabulary and supporting claims with evidence. Finally, we would like to comment on the importance the presence of the tangible object had on the conversation. It was by plucking the strings that Gustavo generated the onomatopoeic labels that served as linguistic footholds for Gyorgy and the other students. Moreover, Gyorgy's contributions appeared to be significantly tied to his experience with the physical object, e.g., through plucking the strings for measuring the tension and frequency of vibrations, and pointing to the string he was referring to. Therefore, we argue that the emergent third space supported Gyorgy's productive disciplinary engagement in the discussion about the connection between the strings' features and pitch.

There are some limitations to this study. While our claim is that learning environments that support the emergence of third spaces invite students to participate, we recognize that not all students are able to do so. Our choices for data collection only give us information on students' productive disciplinary engagement as they publically engaged each other, and it leaves out how students could have been partially engaged in a private way.

It would have been beneficial to ask students to produce individual written text on their ideas about the guitar before the discussion. This would have given us a sense of students' previous experiences with guitars and/or intuitions on the relation between the physical properties of the strings and the characteristics of the sounds produced. Additionally, we acknowledge the range of social dynamics in play during discussions that can promote or hinder certain students' willingness to engage. In this case, the written text could have served as an avenue for students to express themselves without feeling the pressure to participate in a public forum. Finally, although we have made some inferences about the aspects of the learning environment that led to productive disciplinary engagement, it is not fully clear what combinations of features were the critical ones.

Conclusions and Implications

Based on the evidence presented above, we claim that central features of the learning environment that provided access and inclusion in classroom discourse were: (i) tangible nature of class materials; (ii) shared nature of experiential observations; (iii) students' inherent desire to understand their worlds; and (iv) the coexistence and blending of everyday and academic language. We argue that these central features of the learning environment, also central features of scientific inquiry, facilitated and mediated a rich discussion between students about mechanisms, furthering conceptual understanding and belonging. Additionally, the presence of familiar language in these conversations gave access to students who may have felt unsure about their perceived level of understanding and/or language skills. Moreover, students responding to their peers' conjectures, and co-constructing knowledge, is evidence how third spaces distribute authority of knowledge and language among students themselves. Also, the discussion provided evidence of how common and invented terminology can become formalized, in a process resembling the creation of scientific discourse conventions. As it is hypothesized in third spaces, students became comfortable using the invented terminology, allowing them to express themselves and construct knowledge freely, and even to test academic language that was introduced through schooling. Moreover, these emergent third spaces provided opportunities for student to engage in scientific cultural practices, specifically by problematizing phenomena through attending to causal mechanisms, supporting their claims with evidence from observations, and sustaining a group discussion that contributed to the negotiating of meaning and conceptual understanding.

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