Chapter 10
Doing and Talking Science: Engaging ELs in the Discourse of the Science and Engineering Practices

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Introduction

The Next Generation Science Standards (NGSS; NGSS Lead States 2013), and the Common Core State Standards (CCSS; National Governors Association Center for Best Practices and Council of Chief State School Officers 2010) shift teaching and learning across the US to focus on disciplinary, language-rich practices, with broad implications for teaching English learners (ELs). The NGSS calls students to engage deeply and actively in the exploration and discussion of ideas by enacting three interacting dimensions: practices, core ideas, and cross-cutting concepts. Three-dimensional science learning engages students in scientific and engineering practices as they explore phenomena to develop interdisciplinary science ideas in relation to cross-cutting concepts. Similarly, the CCSS (which include standards for literacy in science, as well as in other technical subjects) increased emphasis on critical thinking, problem solving, and analytic tasks in core academic subjects. Together, these standards "implicitly demand students acquire ever-increasing command of language in order to acquire and perform the knowledge and skills articulated" (Council of Chief State School Officers 2012, p. ii). Yet, at a time when the EL population continues to be the most rapidly growing segment of the K-12 student population, instruction of ELs is too often characterized by three persistent problems of practice, each of which we observed in our pre-intervention visits to classrooms:

1. In whole group work, teachers used primarily IRE (teacher *Inquires*, student *Responds*, teacher *Evaluates* by indicating whether that response is correct or

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not) interaction patterns (Schegloff 2007) that focused attention on teacher ideas rather than on student ideas.
2. In collaborative groups, student discourse tended to be focused on procedures and task accomplishment, rather than on meaning-making, and either excluded ELs altogether or placed ELs in the role of listener.
3. Language development was viewed primarily as vocabulary instruction.

Classroom practices such as these are not likely to foster the rich academic discourse through which students learn to reason deeply and critically, express their reasoning, and challenge and critique that of others, nor are they likely to include ELs in that critical discourse. The need for resources to support effective engagement of ELs in these essential academic discourse practices is critical.

This chapter shares findings and materials from the pilot of a professional development (PD) approach that offered science teachers a set of resources to support their facilitation of students' collaborative and discourse-rich reasoning in science, along with the development of the language needed for these critical functions—all of this in ways fully inclusive of ELs as sense-makers along with their classmates.

Participants were four teachers in two schools in a Midwestern school district. Two taught science as part of their Grade 4 curriculum, and two taught science in Grade 7. Although the state had not adopted the NGSS, district administrators had expressed a desire to improve the science outcomes of ELs in the district.

Teacher Preparation Model

Stages of PD and Related Inquiry

All of the teachers were new in at least one significant dimension related to their teaching. Three of the four were teaching science for the first time and had not minored in a science-related field in their preservice training; one of these had just begun her first year of teaching. The fourth teacher had taught science before but was new to the fourth grade. All four were unfamiliar with their science curricula. None of the science curricula in use was inquiry-based. No teacher had more than 6 ELs in classes that averaged 24 students (a common distribution in many non-urban school districts), and the ELs ranged in English proficiency levels from Beginner to Advanced, based on teachers' reports of the annual ESL assessment results.

All teachers participated in a half-day PD on the NGSS and three-dimensional science learning, and on the integrated nature and enactment of the science and engineering practices. The teachers were observed teaching one science lesson, and then interviewed about their learning objectives and foci in the observed lesson and their reflections on student engagement and sense-making. Following this initial observation, teachers participated in a 2-day PD focused on (a) an assets-based approach to EL inclusion in science, (b) the development of opportunities for collaborative sense-making, (c) enactment of the language-intensive science and

Table 10.1 PD and inquiry stages and activities

Participants
2 Grade 4 science teachers
2 Grade 7 science teachers
Half-day PD: NGSS three-dimensional science and enactment of science and engineering practices
Classroom observation 1
Post-observation interview 1
Two-day PD
Assets-based approach to EL inclusion in science
Developing opportunities for collaborative sense-making
Science and engineering practices 2 and 6 (developing models and constructing explanations)
Discourse engagement strategies & resources
Structured lesson reflection 1
20-min phone call
Structured lesson reflection 2
20-min phone call
Structured lesson reflection 3
20-min phone call
Classroom observation 2
Post-observation interview 2
Focus group to explore aspects of resources provided

engineering practices of modeling and explanation (Practices 2 and 6), and (d) resources for the facilitation of students' collaborative sense-making discourse. Subsequently, teachers spoke monthly over 3 months with PD providers via telephone to discuss a Structured Lesson Reflection document the teachers had sent the PD providers the day before. The 20-min phone calls were used to probe various aspects of teachers' ideas and reflections more deeply, and to provide information or suggestions as requested by teachers. After approximately 3.5 months, all teachers were observed and interviewed once again, using the same protocol and similar questions. As a final stage of the information gathering, teachers were interviewed in more detail about their reactions to the resources and PD provided (Table 10.1).

Theoretical Foundation of the PD

Figure 10.1 depicts the assets-based approach to EL inclusion in which this project was grounded. This approach recognizes that ELs come to their science classrooms with multiple ideas about how the world works (green strand), as well as with knowledge about one or more languages in addition to varying degrees of effectiveness with English (blue strand). Given these strengths, they are well able to engage in scientific reasoning and discussion of their reasoning. If educators are successful

Fig. 10.1 Assets-based inclusion of ELs in explanation and modeling in science

in tapping into and leveraging those assets and capacities by positioning students as questioners and thinkers and themselves as facilitators of student reasoning (purple strand) and by engaging ELs with their classmates in the collaborative sense-making practices of science (the words spiraling around the center), both ELs' knowledge of science and their linguistic effectiveness in science will be strengthened. (See also Lee et al. 2013).

The project's focus on ELs as sense-makers in science, along with their English-fluent classmates, is grounded in a *language as action* perspective (van Lier and Walqui 2013). This contrasts with an accumulation model that considers the development of academic English as the building up of progressively more complex syntax and vocabulary to (eventually) accomplish a broader range of functions. This accumulation of necessary linguistic resources is seen as an inner, cognitive event that progresses slowly and sequentially—a perspective often aligned with a deficit model. In an accumulation model, students first come to know (language) and then they do (science). The *language as action* approach views the process quite differently: By doing (science) together, students come to know (language). In other words, language is seen as action and developed through action, and more specifically, through action that occurs among individuals in a shared context. In this sociocultural approach, meaning does not reside solely in language, but is a larger construct developed through negotiated and shared experiences during which participants construct and represent meaning together, only in part, through language (Gee 2005; Rogoff 2008; MacDonald & Molle 2015). Put simply, meaning is not stored language; meaning is stored experience.

In this project, as in the *language as action* approach, shared activity is seen as the engine that drives language development. All students, including those still developing English, are given the opportunity to engage in collaborative reasoning, and are expected and supported to be active sense-makers. In this approach, ELs have the opportunity and support to be initiators of ideas, along with their classmates, rather than simply passive responders. Language development for all students is thus deeply contextualized within interactive sense-making, and instructional attention is focused on students' effectiveness at marshaling the diverse sense-making resources (linguistic and other) they command, rather than on the correctness of their language. For the rapidly growing number of ELs in US classrooms who may require years of English language development before their language is fully proficient, this is an important and supportive shift. ELs can, and do, engage in important reasoning and learning with imperfect language and it is this "doing" that supports their progress toward more effective and, eventually, more correct or more appropriate English.

These affordances of the *language as action* approach align well with the language expectations of the NGSS and three-dimensional science, as illustrated by the following comments:

- "For all students, the emphasis should be on making meaning, on hearing and understanding the contribution of others and on communicating their own ideas in a common effort to build understanding …." (Lee et al. 2013, p. 3).
- "Essentially all of the science and engineering practices require student discourse to be a central element of classroom activity, and, properly managed by the teacher, such discourse includes all students and pushes every student to refine and extend language abilities." (Quinn 2015, p. 14).
- "Only an emphasis on language as action … engages students in the meaningful learning of new disciplinary practices while simultaneously strengthening their language uses in those practices." (Heritage et al. 2015, p. 32)

Efforts to strengthen students' reasoning in science are not easily supported using an atomistic view of academic English as the accumulation of complex syntax and vocabulary. Indeed, as stated by Heritage et al. (2015), "teaching form and function in isolation from real, meaningful, discourse-based communication has not produced generative, transformative learning for ELLs" (p. 31). The *language as action* perspective does, however, focus attention on students' meaning-making and their linguistic effectiveness during interaction with one another around important ideas in science. These examples (Miller and MacDonald 2015) illustrate the important differences in the approaches.

Language goals based on the *form and function* or *accumulation* model:

- Students will compare landforms using descriptive language.
- Students will describe the molecular changes that occurred using the past tense '-ed' form.

Language goals based on the *language as action* approach:

- Students will collaboratively develop a model that explains and predicts patterns in the changes to the land caused by wind and rain.
- Students will collaboratively construct an explanation of the effect of thermal energy on molecular movement.

PD Components

To support teachers in working with the *language as action* perspective and our assets-based approach to EL inclusion in collaborative reasoning in science, the 2-day PD was spent considering elements of the approach and practicing the use of a small set of resources.

Enacting the Science and Engineering Practices Although the disciplinary core ideas of the NGSS are familiar to many, and their relationship to cross-cutting concepts fairly straightforward, the science and engineering practices are less familiar to teachers and require significant changes in science instruction (Windschitl et al. 2011; Lee et al. 2013). The PD focused specifically on two high-leverage practices for ELs that were to be implemented jointly: explanation (because of its language demand) and modeling (to demonstrate the use of models as scaffolds during meaning-making). Facilitators modeled classroom enactment of meaning-making by placing teachers in small groups to consider phenomena shown on video, collaboratively develop models depicting their reasoning about causal forces, and then explain their reasoning, using the models as references. During teachers' explanations, facilitators modeled the Teacher Moves as examples of probing and deepening reasoning.

Creating Opportunities for Collaborative Reasoning Following this demonstration of a collaborative meaning-making activity, PD focused on the role shifts required for both teachers and students when working to strengthen student reasoning in science, summarized in Table 10.2. Given teachers' lack of relevant curricular support materials, considerable PD time was devoted to discussing the benefits of using locally relevant, easily observable phenomena (accessible to ELs) around which to center student reasoning opportunities. A list of such phenomena and their relationship to NGSS disciplinary core ideas and cross-cutting concepts was generated. Teachers were given time and support in selecting a phenomenon with which to initiate an upcoming science unit.

Changing Classroom Interaction Patterns Strengthening students' collaborative reasoning and the language through which much of it is expressed and deepened calls for changes to typical classroom interaction patterns. Much more student talk is needed than typically occurs in many classrooms. The commonly used IRE pat-

Table 10.2 Consideration of changes to teacher and student roles in science

Teacher role: Shape the discussion to promote collaborative meaning-making	**Student role:** Work with classmates to understand unseen forces behind phenomena
Create the need to interact meaningfully	Be responsible for following ideas; listen carefully and track the idea's development
Facilitate students' collaborative meaning-making	Check for accurate understanding of others' statements; persist until clear mutual understanding is achieved
Model effective language as needed and discuss reasons for linguistic choices	Consider the ideas of others as sensible first, and then take up the idea or discard the idea based on evidence
Design for ELs to be initiators as well as responders in meaning-making interactions	Compare evolving explanations to other information; does it make sense? Is something missing?
Promote student-to-student interactions	Respond to ideas; support or challenge or build on ideas
Support perseverance in understanding and meaning-making	

tern may move a class quickly through a review of known information (known, that is, to the teacher) or may move a class toward the teacher's predetermined goal, but it provides few opportunities for students to talk. Student input is usually constrained to very truncated responses, and those for only the few students able to formulate responses very quickly—a group from which ELs are frequently excluded. IRE exchanges offer few opportunities for students to use language to express and engage in extended reasoning. This project focused on three ways to increase student opportunities for meaningful language use: (1) the use of small group work to focus on challenges in reasoning, rather than on task accomplishment, and in ways that ensure full participation by all group members, including ELs; (2) the use of Teacher Moves to promote more extensive discussion and include additional students in reasoning-focused whole-class interactions; and (3) the use of Teacher Moves and Student Moves to promote increased student-to-student reasoning-focused interchanges during whole class time and small group work. Teachers' enactment of this approach was further supported during brief monthly contacts.

Materials

Teacher Moves: Discourse Facilitation Moves for Teachers

Although teacher education literature has focused attention on supporting teachers in learning more student-focused interaction patterns (Chapin et al. 2003; Michaels and O'Connor 2012; Windschitl et al. 2011), these resources are not yet well known by teachers. Given their critical role in our approach, a small set of discourse

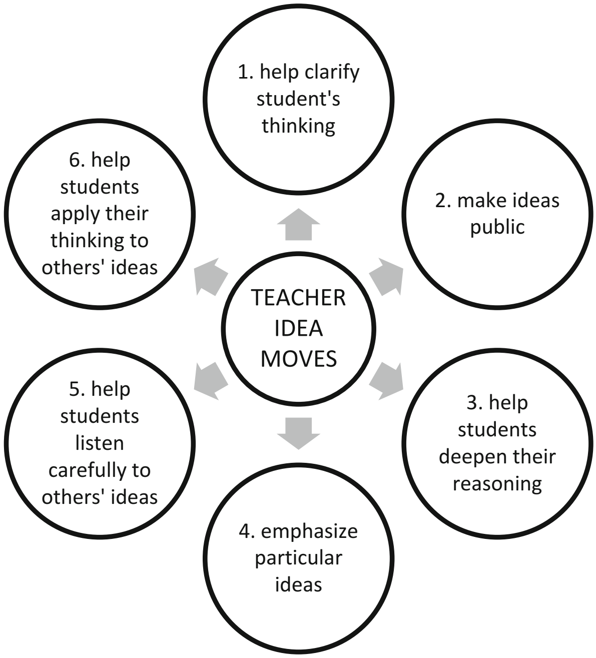

Fig. 10.2 Meta-cognitive framework for teacher moves

facilitation moves was created and organized to form a compact, six-category set of Teacher Moves. A graphic illustrating the six different purposes by which the Teacher Moves were organized was developed (shown below in Fig. 10.2), to serve as both a meta-cognitive framework and a quick visual reminder to teachers of their options when student ideas were on the table. In each category, examples were provided, some of which are shown in Table 10.3, below.

Teacher Moves serve three purposes, which can be considered sequential:

1. Clarify individual student ideas and surface them for consideration by the group (Moves 1 and 2)
2. Probe and deepen expressed reasoning (Moves 2, 3, and 4)
3. Promote student-to-student interchanges (Moves 5 and 6)

The Teacher Moves all support teacher efforts to extend additional invitations for student talk and reasoning. By not closing down interactions with the typical IRE third move of Evaluation, but instead asking another question or bouncing the idea to another student, the teacher provides additional opportunities for students to reason and to express their reasoning (Greeno 2015). During the PD, it was suggested that teachers take up one or two moves at a time, focusing on the sequential nature and allowing themselves and their students time to adjust to new expectations for classroom interaction.

Table 10.3 Examples of teacher moves

Teacher moves	Examples
1. Help clarify students' thinking	Provide individual thinking time and pair activities to help students express the "first draft" of their idea
	Charge student pairs with questioning and supporting one another until ideas expressed are understood
	Provide 10–20 s of wait time both before and after student responses
	"Can you show us what you mean?" "Can you draw that?" "Can you say more about that?"
2. Make idea public and available for discussion	"Tell us more about what you're thinking."
	Revoice an idea to repair or model clearer language, but ensure that the ownership of the idea remains in student's hands. "Did I say your idea correctly? Is that what you were thinking, or was it different?"
3. Help students deepen their reasoning	"Can someone give me an example of that?"
	"How could we test that?"
	"What do we need to know more about now?"
4. Emphasize particular ideas	Attend to all ideas, and be explicit about putting some on hold.
	Re-broadcast generative ideas by revoicing, or by asking a student to paraphrase. This allows additional processing time for all.
	"That's interesting. Can you say that again for us?" "Will someone re-tell that idea for us?" "So, are you saying that…?"
5. Help students listen carefully to others' ideas	"Who can restate that for us?"
	"Who wants to explain the reasoning Group A used?"
	"How is that idea different from Mary's?"
6. Help students apply their thinking to others' ideas	"You look uncertain. What can you ask X to find out more?"
	"How does that idea connect to what Group A talked about?"
	"Which explanation is most like your group's? Talk to them and find out how they are different."

Student Moves: Discourse Engagement Moves for Students

Recent research and writing on academic discourse has focused attention on strengthening students' linguistic expression of complex thinking. In particular, the work of Zwiers et al. (2014) has provided examples of discipline-specific Constructive Conversation Skills posters to provide students with reminders of linguistic structures they could use to enact important academic tasks, such as the generation of multiple approaches and the negotiation of ideas. The Student Moves tool developed for this project was focused more broadly on seven general responses students could make to an idea. To support all students in exercising their agency as speakers in collaborative reasoning interactions, the Student Moves tool, like the Teacher Moves tool, included a graphic representation of the meta-cognitive framework (Fig. 10.3) and linguistic examples to accomplish these seven types of responses to ideas (Table 10.4). To support ELs' inclusion, the language examples were written for three broadly conceptualized levels of English language

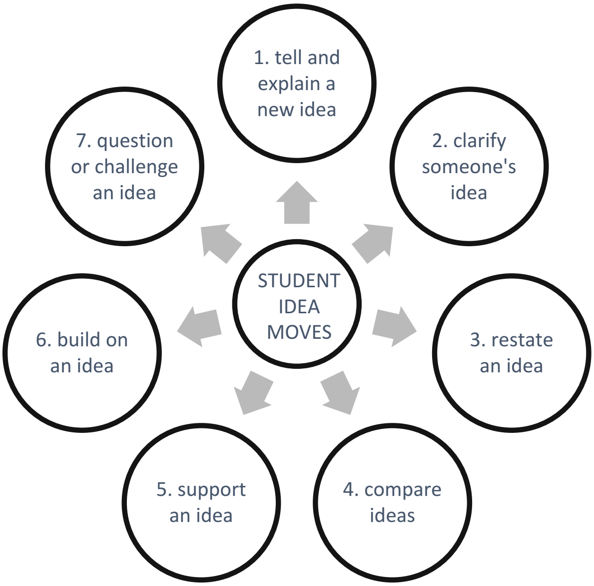

Fig. 10.3 Meta-cognitive framework for student moves

Table 10.4 Linguistic examples of student moves

Student Moves	Examples
1. Tell and explain a new idea	"I think…"
	"The evidence for that is…"
	"Since both situations are similar, we could…"
2. Clarify an idea	"Say again, please."
	"What did you mean when you said…"
	"I wonder if what you're saying is…"
3. Restate an idea	"He said…"
	"In other words, …"
	"The suggestion was made that we…"
4. Compare ideas	"Same thing."
	"Our idea is better because…"
	"The other method would be a better test of …"
5. Support an idea	"Good idea because…"
	"Remember, in our book it said…"
	"The advantage of that method would be …"
6. Build on an idea	"Let's try it."
	"That's what we should do next."
	"That idea would help us figure out whether …"
7. Question or challenge an idea	"I don't think so."
	"But what about…"
	"Isn't there a more efficient way to…"

proficiency, based on the Reference Performance Level Descriptors designed to include or translate English language proficiency definitions across most US states (Cook and MacDonald 2014).

Since academic discourse requires interaction among speakers, one of whom is often the teacher, the Student Moves were designed to work in tandem with Teacher Moves by providing linguistic resources for students to respond to the teacher's discourse facilitation and to collaborate with one another during small group work. During the PD, it was suggested that teachers first introduce the meta-cognitive framework to students, then a few sentence frames, and that they generate additional sentence frames with students, as well as capturing examples of student-generated moves when they occurred. It was also suggested that students have some personal representation of the Student Moves available, rather than being dependent on classroom posters, to increase their ownership of the Student Moves and support their independent action in small group work.

Implementation

Participating teachers devoted considerable time and effort to creating or adapting classroom activities to provide meaningful opportunities for collaborative, extended student reasoning.

- Grade 4 teachers adapted a scripted ball and ramp activity originally intended to demonstrate ideas of force and motion by adding an additional variable (changes in ramp height) and asking students to model and explain the forces at work. After students compared models and explanations, they were asked to collaboratively develop ways to test their ideas. One teacher noted how pleased she was to hear her ELs debating alternate ideas with their peers.
- Grade 4 teachers adapted an activity that involved shooting materials into the air with levers of different length (focused originally on providing data with which to practice graphing skills, with little focus on reasoning about the relationships) to enable students to reason further about relationships between potential and kinetic energy.
- Grade 7 teachers focused attention on a local phenomenon (the daily, early morning observation of clouds of water vapor over a heavily forested bluff) to introduce a unit on transpiration in plants. Over consecutive days, student groups discussed and developed models that they shared and then revised. One teacher noted how actively his ELs (who had formerly been in an EL-only group) participated with others, and how patient and helpful their peers were when ELs were introducing and explaining their ideas.
- Grade 7 teachers introduced a unit on ecosystem carrying capacity by creating a predator-prey game, in which wolves were the predators, linking to local concerns about wolf predation. All students played various parts (vigorously and noisily!) and noted the differential outcomes when ratios of predators, decomposers, etc. were changed. During the activity, students were heard explaining

excitedly to one another their understandings that if they partnered up in various ways, they could prolong their survival. Although both teachers were new to science, they expressed a strong belief that this activity resulted in greater engagement with the science than would the reading assignment suggested as an opening activity in their textbook. One teacher also noted how pleased she was that all of her students learned the associated vocabulary "simply through using it," and that she no longer believed she had to pre-teach vocabulary to her ELs.

As teachers gained confidence in developing phenomenon-based activities, they began to use a greater variety of Teacher Moves. Reflecting on her own learning, one teacher noted that when she failed to allow sufficient wait time for students to think and respond, her attempts to support student reasoning were always unsuccessful. She remarked that she used to believe that classroom interactions needed to happen at a rapid pace, so she would not lose students if they got bored, and also noted that her nervousness as a new teacher made it difficult for her to endure silent moments. However, at the end of this project, she observed that her prior belief and practice were interfering with her students' opportunity to think deeply and critically, and she resolved to work toward adjusting her practice. This teacher's remarks also serve as an illustration of a changed perspective on engagement: from engagement as behavior to engagement as reasoning.

Outcomes

Initially, like their district and school colleagues, teachers used primarily teacher-fronted lessons based on textbook chapters or on scripted activities that demonstrated rather than explored science constructs, and used classroom interaction patterns characterized by whole group lecture and classic IRE/F interactions. Following the 2-day PD, teachers in the participant group began to make significant changes.

Changes in Classroom Structures and Activity

Grade 7 teachers began to place students into small groups focused on the collaborative development of questions, models and possible explanations. Grade 4 teachers, who had already placed students in functional, task-focused groups, changed the focus of small group work from completing worksheets to students' collaborative development of explanations. Additionally, teacher comments indicated a change in what they considered engagement. Initially, engagement was seen as students being on-task and not disruptive, but later comments suggested that teachers considered engagement to be students' cognitive engagement with the ideas being discussed. All teachers reported an increase in student engagement in science.

Changes Specific to ELs

In one classroom in which all ELs had previously been grouped together with an ESL paraprofessional, ELs were integrated into small working groups with their English-fluent peers. All teachers reported being pleased at how well ELs were able to participate in the activities with minimal additional scaffolding by the teacher, and two of the four remarked how pleased they were to find that ELs were able to learn new vocabulary through using it in the midst of activities, and that they no longer felt the need to use class time to pre-teach vocabulary. In describing the changes observed, teachers remarked:

> One of our struggling ELs took the risk to share an idea he was not certain about, and then kept talking to work through his thinking again – all in front of the whole class.
>
> Our ELs view themselves differently because they're able to talk about ideas now. That's made a huge impact on their perceptions of themselves as learners. They've always been smart, but now I think they feel smart.

Discourse Facilitation Tools and Opportunities for Student Reasoning

Teacher Appropriation of the Discourse Facilitation Tools Review and coding of interview transcripts and field notes revealed an interactive relationship among the use of the separate discourse tools and teachers' success at creating meaning-making opportunities, as depicted in Fig. 10.4.

When able to create effective opportunities for student reasoning (experiences and driving questions that stimulated rich, extended discussion of ideas), teachers were more likely to use a variety of Teacher Moves to probe and deepen students' reasoning. When the attempted meaning-making opportunities were less rich

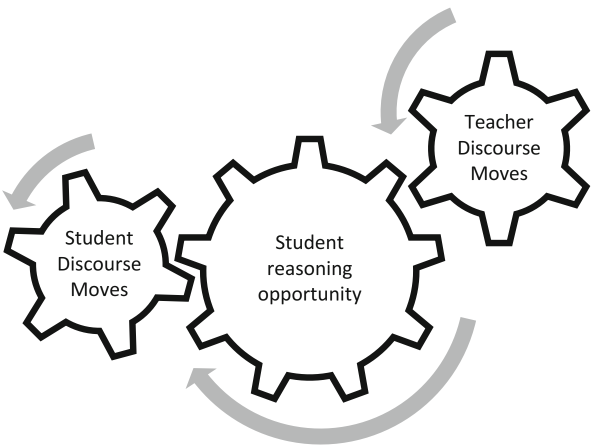

Fig. 10.4 Interaction of student reasoning opportunity with discourse moves

(e.g., fewer or less complex ideas about which to reason collaboratively), teachers used fewer and less varied Teacher Moves, sometimes simply repeating “Why?” in response to students’ proffered explanations. The interactive nature between opportunity to reason and Teacher Moves is apparent. With nothing meaningful to explore or about which to reason collaboratively, the student collaborative reasoning process is too short-lived to require Teacher Moves, and teacher attempts to gain experience in using these discourse facilitation moves fall flat.

Conversely, if rich opportunities for sustained collaborative reasoning are provided but are met only with surfacing, introductory discourse moves (e.g., the repetition of “Why?”), the resulting classroom discussion resembles the “popcorn” pattern in which individual ideas are neither examined nor set in relation to one another for further exploration by students. Although even this introductory Teacher Move does result in increased exposure of student ideas (a desired outcome), if not followed by Teacher Moves that lead students to consider and react to others’ ideas, classroom interaction does not move in the desired direction of strengthening students’ collaborative reasoning. Thus, teachers’ opportunities for successful experience with the Teacher Moves requires the creation, first, of a student experience that has the potential to stimulate sustained reasoning. With such a component in place, teachers have the opportunity to practice and develop effectiveness in their discourse facilitation skills.

Challenges in Providing Meaningful Opportunities for Student Reasoning The teachers in our project (none of whom were able to draw on robust experiences in teaching science) found it challenging to develop effective meaning-making opportunities for students. Lacking relevant curricular support materials, teachers visited multiple websites and resources to find and vet activities to fit their curriculum. Grade 4 teachers modified the scripted activities in the school’s commercial science activity kits to stimulate the deep exploration of a phenomenon and the modeling of possible causal forces. However, the challenge of leveraging meaningful phenomena was especially difficult for the Grade 7 teachers, who taught three or four other subjects in addition to science, had only a traditional textbook series focused on the delivery and subsequent testing of information, and had few materials suited for hands-on student activity. In the third and final month of the project, these teachers were able to streamline the lesson revision process somewhat by collaborating to identify the big ideas and cross-cutting concepts to which their textbook units might be linked, and to search out activities based on the disciplinary core ideas and questions from The Framework for K-12 Science education (National Research Council, 2012).

The teachers in the project occasionally encountered difficulty in reasoning about science ideas. At times, the teachers appeared at a loss when attempting to negotiate the multiple student ideas expressed to develop deeper conceptual understanding. When they were not confident about the science concepts, they expressed uncertainty about which ideas to revoice or probe more deeply or set in relation to one another, and the facilitation around ideas reverted to IRE or declarative knowledge or definitions. Our hypothesis is that this breakdown of facilitation correlated with a lack of deep understanding of the phenomenon they were exploring with students. Because of the paucity of teacher materials that provided the conceptual frameworks involved in explaining phenomena, teachers would have benefited from additional resources and guidance to help fill in those gaps.

The amount of difficulty teachers encountered before they experienced some effectiveness in creating opportunities for student reasoning resulted in a sequential nature in their enactment of the discourse tools. It was only after teachers had achieved some degree of effectiveness in creating opportunities for student reasoning that they began to experiment more frequently with the variety of Teacher Moves. Thus, the PD pilot did not provide adequate opportunity for teachers to experience the interactive relationship among the three components: (1) reasoning opportunity, (2) Teacher Moves, and (3) Student Moves. The Grade 4 teachers did introduce the Student Moves to their students early in the process, using only the linguistic element of the Student Moves (the sentence frames) to establish norms for respectful classroom conversation. At the end of the 3 months, they had just begun to incorporate these moves into small group activities. Grade 7 teachers did not use the Student Moves at all, and at the end of the project, one teacher noted these as the next step and regretted that the PD resources to support their introduction of Student Moves in their classrooms would no longer be available.

This slower-paced and more sequential aspect to teachers' experimentation with the tools is in sharp contrast to what occurred with a small group of mathematics teachers engaged in a parallel pilot of these resources in a different district. This group of highly experienced mathematics teachers, familiar with their curricula and grade-levels, experienced the same need to develop meaning-making opportunities, but progressed more quickly to the point of effectiveness with this component and began almost immediately to practice their use of the Teacher Moves and to introduce Student Moves as tools for collaborative small group reasoning. These teachers were able to experience the benefits of all three components (opportunity, Teacher Moves, and Student Moves) working interactively, and noted the power of the positive classroom experience in heightening their commitment to the work of developing their discourse facilitation skills. One mathematics teacher discussed both her initial struggle in using the approach, and her increased confidence in their students' understanding:

> I work a lot harder now. Sometimes, it's just easier to go by the textbook and say, "OK, this is why it works—let me show you." But there's no connection, there's no meaning behind it. And that's the hardest thing, I think: to change that teacher behavior of having to control the conversation, and just give it up to the group to talk until they figure it out. There was one day students spent at least 20 minutes in a discussion of one idea, and it about killed me to spend that much time talking about it, but now, you could ask any kid on my team and they could explain it and tell you exactly why it's that way. I have never felt so confident that my students understand things, ever.

This contrast between the experiences of the science and mathematics teachers suggests that revision of the PD approach to include additional resources that would enable science teachers to more quickly experience the interaction of the three components should be considered.

Integration of Science and Engineering Practices

Although the science and engineering practices were unknown to teachers at the project onset, teachers quickly began to integrate Explanation and Modeling (Practices 2 and 6) into their lessons. All four teachers began to create opportunities for students to collaboratively consider phenomena and driving questions that elicited multiple possible explanations to be further examined, and began to incorporate the Teacher Moves to surface, probe, and deepen student explanations. All four teachers began to integrate the practice of modeling into their meaning-making focused instruction. Although not yet fully leveraging models as explanatory devices (Mayer and Krajcik 2015), teachers did note the value of drawn models as supports to which ELs could refer when not yet able to convey intended meanings solely with words. Thus, teachers' emergent integration of modeling into their lessons enabled ELs to more frequently and successfully join their peers in collaborative meaning-making.

Summation

Science teachers using this collaborative meaning-making approach with minimal support made significant changes in shifting their practice to focus on active engagement of students in the exploration and discussion of ideas, in ways that engaged ELs as sense-makers along with their classmates. The brief pilot of this approach, with its three interacting components (opportunity for student reasoning, teacher discourse facilitation moves, and student discourse engagement moves), offers resources and insights to help science teachers meet the critical need for materials and methods to enact the three-dimensional vision of science in ways that include the rapidly growing number of ELs in US classrooms.

Positive Effects of the Pilot

In relation the three persistent problems of practice noted in the introduction, the positive effects of this pilot suggest that:

- When given resources like the Teacher Moves and some support for the development of meaning-making opportunities for students, teachers can begin to change their interaction patterns to more actively engage student in interactions, and deepen student reasoning about ideas;
- When given a tool such as the Student Moves, with its meta-cognitive framework and language examples, ELs can and do join in collaborative meaning-making, acting as initiators of ideas rather than simply as passive responders. Similarly, when it is clear that ELs' ideas are being solicited and valued, non-EL classmates

persevere in efforts to comprehend ELs and to assist them in their explanations, thus enacting the negotiation of meaning-making that drives language development for ELs.

- Teachers enacting this approach can come to understand through their lived experience that ELs' language development is not dependent on decontextualized pre-teaching of language components, but can be supported in the midst of science instruction by engaging all students in the rich, collaborative discussion of ideas.

Possible Shortcomings of the Approach

Observing teachers' gradual appropriation of these resources has also pointed out shortcomings in the PD approach, which should be addressed by those wishing to follow up on this. The approach underestimated the degree of difficulty teachers would experience in creating opportunities for student reasoning. Although examples were provided, these were not sufficient to enable teachers to move quickly enough into trying out the Teacher Move and Student Moves. Thus, the integration of the three components did not occur quickly enough to enable these teachers to experience the benefits of all three components working interactively, which had heightened and seemed to hasten the development of confidence in the discourse facilitation efforts of a separate group of mathematics teachers in a related PD pilot. Future efforts might include the provision of sample activities related to grade-level units, to jump-start teachers' experience with the interaction of the three components. Additionally, it would be helpful to have at hand resources that provide accessible explanations of the science constructs related to a number of phenomena. Lack of teachers' confidence in their own science understanding may affect both their confidence in adopting interaction moves that open up the floor to student ideas as well as their ability to marshal those ideas toward a deeper understanding.

Further Considerations

Unaddressed in this pilot, but important to consider in more extended versions, is the need to provide teachers constructs by which to monitor and support students' English language development. The need to develop teachers' language awareness is present in any approach to content instruction for ELs. Those working from a "language as accumulation" approach are likely to focus on increased correctness. For those working from a *language as action* perspective, a different lens is needed. It should not be focused on correctness, but on effectiveness; it should support students in using English to more effectively explain and argue in support of their ideas. The components and dimensions of increasing effectiveness are worthy of continued consideration and exploration.

Pedagogical approaches that focus on increasing ELs' effectiveness in English while developing their science knowledge are critical to ELs' achievement in the new standards. The NGSS focus attention on a process-based goal, but they do not provide the pathway toward that goal. For that goal to be achieved, new approaches to teaching and learning are needed to inform curricula that are fully inclusive of ELs. Teachers need support and resources to enact the changes described in the NGSS, and to consider the additional and critical aspect of students' language development. The approach shared in this chapter can help teachers mediate the new standards into practice, for all students. This confidence was first expressed by science teachers at the end of a presentation of this approach at an NSTA conference. Several teachers remarked, "We know this is how we're supposed to teach, but nobody has shown us how to do it. This shows us how!"

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