Patterns of Classroom Talk Through Participation in Discourse-Focused Teacher Professional Development

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Abstract: The Next Generation Science Standards (NGSS) reforms in the United States present a number of serious learning challenges for in-service teachers. As states and school districts are assuming responsibility for the new standards, there are few professional development (PD) models for how to help working teachers meet these challenges. This study presents an analysis of teachers' practice in the second of three years of professional development aimed at helping them learn to enact instruction aligned with the NGSS. The analysis focuses on changes to how teachers organize whole class discussions, looking particularly at how teachers support student-student dialogue. Comparing discussions from spot observations of teaching to PD-supported lessons, data suggest teachers struggle in both contexts to support productive student-student talk, although they are modestly more successful in the PD context. Conclusions from this analysis include that PD should provide clear models of productive discourse.

Introduction

In the United States, most states have adopted versions of the Next Generation Science Standards (NGSS Lead States, 2013). In California, with more than 6 million students in public schools, teachers in grades 7-12 are responsible for teaching to the new standards as of the 2017-18 school year. The shift from business as usual to the new standards entails radical changes to teaching practice. One very big change is that the NGSS ask teachers to organize curriculum around natural phenomena that require explanation, rather than around concepts students should learn. This shift is intended to subordinate science concepts to the phenomena they help to explain. A second change is that students should engage in science practices to explain and model phenomena, such that concepts are learned through practices of investigation, modeling, explanation, and so on, rather than maintain a false dichotomy between science concepts and processes. This reorganization of instruction requires a third shift in teaching practice in order to be successful: teachers must reorganize the discursive practices of their classrooms. Real engagement in science practice entails talking through the myriad questions and disagreements that naturally emerge during any real inquiry, in order to stabilize resolutions to empirical and conceptual problems that enable continued progress (Manz, 2014). Given the rarity of inquiry-oriented science instruction prior to the development of NGSS (Banilower, Smith, Weiss, & Pasley, 2006), it is safe to say the demands of the NGSS pose significant challenges for practicing teachers.

This study draws on data collected during the second year of a three-year professional development project. The overall project aims to help teachers shift their practice toward the kinds of science learning envisioned by NGSS, learning that relies on students' joint construction of scientific knowledge, and of the practices that create such knowledge. Our view on creating such learning environments centers on developing productive disciplinary engagement (Engle & Conant, 2002), by focusing on framing instructional activities in ways that make students accountable to each other and to the discipline. This requires centering classroom discourse as the main lever of instructional change. Our approach has two stages. In the first stage, our aim is to help teachers "open up" their instructional activities to give students more agency and responsibility to negotiate and enact practices of experimentation, modeling, data analysis, argument, and so on. Productive disciplinary discourse can only emerge in such contexts, where students legitimately have to grapple with how to engage in the work. The second stage aims to help teachers learn productive talk moves that can help them manage the student discourse arising from these more open opportunities to do science. Here we draw on observations of class discussions for evidence that our PD approach is changing classroom discourse. We assume teachers, as learners, move along different trajectories in this work, and thus discourse patterns will vary. Here we describe variations in discourse patterns among teachers and how they change over the course of a year of professional development. These patterns of change provide insights into particular challenges teachers have in promoting a more expansive, productive disciplinary discourse, and how PD might support them.

Methods

The primary question we ask in this study is how participation in PD supported teachers in changing the nature of their whole class discussions. We use the character of whole-class discussions as an indicator of how teachers' practice may or may not be moving toward alignment with NGSS. Whole class discussions are perhaps the primary site where norms and standards of accountability are developed and spread (Engle & Conant, 2002; Mercer, 2008; Rosebery, Warren, & Conant, 1992). We are not claiming that productive discourse happens only, or even mostly, in whole-class discussions. We simply assert that analyzing the qualities of teachers and students' contributions to whole-class discussions provides an indicator of the epistemic agency students exercise in classrooms, and that such agency is central to productive disciplinary engagement (Engle, 2006; Michaels, O'Connor, & Resnick, 2008).

Study context

The data for this analysis are drawn from the second of a three-year professional development project. Professional development activities are led by dedicated staff experienced in science teacher professional development, in collaboration with research staff on the project. Each year of PD is organized as a 3-day summer institute (18 hours) where participating teachers explore a small set of issues to focus on during the school year. During the school year, teachers work in subject matter teams within grade bands (e.g., grade 8 physical sciences, high school biology) through two cycles of curriculum revision modeled on lesson study (Fernandez & Chokshi, 2002). Each lesson study cycle is carried out through 4 PD sessions (16h), an instructional round day (6h), and a final debrief session (2h). This sums to about 66 PD contact hours per year.

Lesson study cycles are organized around each teacher team choosing one unit of instruction to revise. During the first year of PD, 2015-16, revisions focused on creating opportunities for students to engage in one of the 8 science and engineering practices (SEPs) described in the NGSS. As teachers began this work in the first year, we found they understood SEPs as instructional means for either reinforcing concepts or assessing student understanding (Sandoval, Kawasaki, Cournoyer, & Rodriguez, 2016), rather than as intellectual means to develop an understanding of the natural world. Most of our teachers either did not believe their students could engage in something like authentic practice without being told key science concepts in advance, or themselves showed superficial understanding of science practice (Kawasaki, Sandoval, & Rodriguez, 2017). As a means of supporting teachers' developing understanding, we provided them with the NGSS storyline tool (Reiser, Fumagalli, & Novak, 2015), a template for framing instructional units around an anchoring phenomenon and a series of questions that can organize instructional activities to generate answers that accumulate to an overarching explanation of the phenomenon.

During the second year of PD, teacher teams used storyline development as the primary means to organize their instructional revision work. PD staff pushed teachers particularly to focus on how they framed anchoring phenomena as objects of study, and how they framed subsequent instructional activities in relation to the anchoring phenomenon of a unit. Framing, broadly, refers to how we use speech to organize and interpret an understanding of social interaction (Goffman, 1974). Framing is an interactional accomplishment. In classrooms we can ask how students and teachers frame their activity, how they make sense of what is, or should be, going on and thus how to participate (Berland & Hammer, 2012). As we worked with teachers during the second year, PD activities focused on helping teachers think about how they could frame instructional activity such that students would be more likely to engage in productive disciplinary dialogues. This focus on framing emerged from our analysis of the difficulties teachers had in the first year of PD to legitimately open space for students to exercise epistemic agency (Sandoval et al., 2016).

Participants

The teachers involved in the project work in an urban school district in the western United States, serving a population of approximately 30,000 students. Ninety-five percent of students identify as Latino, more than two-thirds qualify for free or reduced lunch, and approximately 30% are classified as English learners. All participants (N = 25) teach science in middle school (9 women, 3 men) or high school (10 women, 4 men). All participating teachers are designated as lead teachers at their schools, with responsibility for helping their colleagues implement NGSS. Most of the high school teachers participating in the project worked with this project's professional development staff during the year prior to the start of this project. Teachers self-organized themselves into grade/subject teams to pursue their lesson study work. There were seven teams during the first year, collapsed into six during the second year because two teachers were unable to consistently attend PD sessions.

Data sources and analysis

The data for the present analysis come from video records of instruction collected throughout our second year of work with these teachers, 2016-17. During the early part of the fall of the school year (late August – October, 2016) we recorded one class meeting of each teacher, suggested by them as showing their best effort to enact NGSS-aligned teaching. We repeated this round of spot observations during the spring of 2017 (April – June), again for each teacher. During each instructional round, in November, 2016 and April, 2017, we video recorded two "research lessons" from each team, producing 12 videos from each round. The video corpus comprises 74 recorded lessons (50 spot observations, 24 research lessons), averaging 46 minutes apiece. This analysis works from the videos that have currently been transcribed: 25 from Fall 2016 (F16), 14 from Spring 2016 (S16), and 13 of the 24 videos from the two instructional rounds of research lessons.

To analyze the roles teachers and students played in discussions across such a large sample of video recordings, we applied the low-inference discourse observation protocol (LIDO; Michaels & O'Connor, 2015). LIDO counts the frequencies of categories of teacher and student talk moves in whole-class discussions (Table 1). There are six teacher codes and six corresponding student codes. Three codes for teacher talk address dialogic scaffolds (T1-T3), and correspond with codes for student dialogue (S1-S3). Three other teacher codes (T4-T6) characterize the nature of questions teachers ask. One code for student talk (S4) concerns whether students ask questions related to the lesson content, and two (S5, S6) capture how students respond to teacher questions. Under our framework of productive disciplinary discourse, we would prefer to see more dialogic scaffolds and dialogic responses from students, and open-ended questions from teachers with elaborated responses from students.

Table 1: LIDO codes for teacher and student contributions to whole-class discussions

Code	Description	Code	Description
Dialogic Scaffolds		Student Dialogue	
T1	Get student(s) to respond to another student's turn	S1	Student addresses another student
T2	Ask student to explain, clarify, or provide reasoning	S2	Student refers to another student's contribution in some way
T3	Attempts to get student to continue speaking	S3	Student provides evidence or reasoning to support their claim
Teacher Questions		Student Responses	
T4	Poses truly open, contestable question	S4	Student asks the teacher a question about lesson content
T5	Poses semi-open question, with a circumscribed answer set	S5	Other elaborated turn, longer than a simple clause
T6	Poses a closed, uncontestable question, or a test question	S6	Turn is a simple clause or less

We carried out this analysis in several stages. First, video records of each observed lesson across the 4 time points was transcribed in full. Then, segments of whole class discussion were identified and marked. Marked transcript segments were then coded, first for teacher codes then for student. Researchers calibrated our coding by first collectively coding 4 transcripts and discussing discrepant code assignments until they were resolved. Following calibration, the remaining transcripts were coded independently by the second author. Since each lesson varied in the amount of whole class discussion, code frequencies were standardized by dividing each code count by the total number of counts in that category (teacher or student).

Given the uneven distribution of transcripts across time points (and instructional contexts) we collapsed coding results from F16 and S17 into a single group we call "spot observations," and we consider the 13 transcripts from the lesson study rounds as a single group of "research lessons." To explore our question of how PD may be promoting change, we conducted paired-samples t-tests comparing the frequency of teacher dialogic scaffolds (T1-T3), and student-student dialogue (S1 & S2), and student justifications of reasoning (S3).

Findings

We first present the overall pattern of dialogic interactions observable in our video records, explicitly comparing spot observations to research lessons. Then, we provide brief examples of the nature of whole class discussion in both instructional contexts to provide a concrete sense of what the numbers describe.

Patterns of teacher and student talk moves

Overall, across all of the lessons we observed, whole class talk was dominated by what appears to be traditional triadic dialogue (initiate-response-evaluate, Mehan, 1979), as can be seen in Table 2. (The numbers in this table are standardized proportions of the frequency of each code in relation to the total frequency of codes in that category, teacher or student). The most common talk move from teachers, by far, was to ask a closed-ended question (T6), which were, unsurprisingly, replied to with simple, unelaborated responses (S6). Even during research lessons (IR3 and IR4 in Table 2), the sample of teachers we observed continued to ask mainly closed-ended questions.

Table 2: Standardized proportions of LIDO talk moves in each observation period

		Dialogic Scaffolds			Teacher Questions			Student Dialogue			Student Responses		
	N	T1	T2	T3	T4	T5	T6	S1	S2	S3	S4	S5	S6
F16	25	0.01	0.08	0.05	0.06	0.22	0.58	0.01	0.01	0.04	0.04	0.18	0.72
S17	14	0.00	0.03	0.03	0.01	0.15	0.77	0.01	0.02	0.04	0.01	0.26	0.66
IR3	6	0.02	0.12	0.06	0.01	0.15	0.64	0.04	0.02	0.12	0.02	0.10	0.70
IR4	7	0.02	0.10	0.05	0.00	0.20	0.63	0.03	0.04	0.14	0.01	0.16	0.61

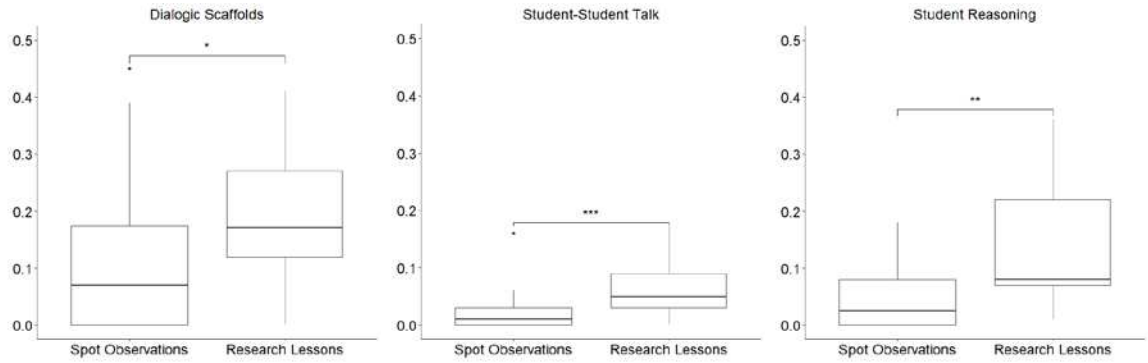

Figure 1. Discourse differences between spot and research lesson observations in teacher dialogic scaffolds, student-student talk, and student justification of reasoning.

During the research lessons, then, teachers were more likely to elicit student reasoning about the topics under discussion and, naturally, students were thus more likely to provide that reasoning. While there is more student-student talk during the research lessons, these are not truly dialogic discussions in which students challenge each others' ideas and strive to reach a consensus understanding.

Examples of discussions across contexts

The quantitative patterns in these data suggest this group of teachers were, on one hand, beginning to enact discursive strategies consistent with our professional development and aligned with NGSS, but, on the other hand, struggled to extend these strategies into their regular classroom instruction. We present two excerpts from one teacher to illustrate this struggle. Ms. Grant (a pseudonym) used a relatively high number, compared to her peers, of dialogic scaffolds in the research lesson we observed her teach (during IR3), but her spot observation during S17 looked very typical of triadic dialogue. Comparing the nature of these discussions suggests some of the stuggles Ms. Grant and her colleagues navigate to learn the new reforms.

Spot observation: Standard I-R-E

For the Spring 2017 observation, Ms. Grant invited us to observe an activity about natural selection. Working in groups, students timed each other conducting a series of tasks with and without the use of their thumbs (taping down thumbs and trying to open a door, or tie a shoe, is a classic activity in the US to demonstrate selective fitness of traits). Ms. Grant opened the class with general instructions for the activity, then she went from group to group to check on their progress. After about a half hour, she brings the class together to review their results, although she specifically tells groups who haven't finished all of the tests to continue to do so. She calls one group to share their data, displaying their recorded data for the class, through a projector. The excerpt below starts with Ms. Grant reviewing the data the group recorded, after one group member has claimed that the "primates" completed tasks faster than "non-primates" (students whose thumbs had been taped against their hands):

1 *Teacher:* This is 54 seconds, this is 47 seconds, yes?

2 *S1:* *[Inaudible comment]*

3 *Teacher:* That's 47. So it actually took the primate longer than the non-primate.

4 *S1:* Those are not seconds. *[Inaudible comment]*.

5 *Teacher:* Yeah, but regardless this is more and this is less so it kind of rebuttals what you're claiming. So why do you think it is in this activity that the bottlecap it took longer for the primate than the non-primate? Is there something else you could have done differently in the experiment? Is there something that made the results come out differently? Okay, let's think about this. You guys see this, primates are this, right? Primates have the thumbs, correct? The non-primates do not have thumbs, right? But you guys said that you think that the primates have a better chance of getting the activities done quicker, right? But right here, does this data support that? Does this evidence support that?

6 *S1:* No.

7 *Teacher:* No. Can you tell me why it doesn't support it or what could have caused this result in your experiment? Think about how you actually conducted the experiment. So who is this?

8 *S1:* Brian.

9 *Teacher:* Brian? And who is this?

10 *S1:* Me.

11 *Teacher:* Okay. You guys see that, right? You heard that? This is Brian and this is Anthony. Those are two separate people. And remember, the primates are supposed to be taped up tightly and they're not supposed to have any mobility of their thumb. So why is it do you think that the non-primate got it done quicker than this? Can you guys explain to us how you actually – what did you do with the bottlecap? Explain to us the procedure, the process. What did you do? You took the bottle and then what?

Notice that Ms. Grant notices that the data the group presents supports their claim that students who could use their thumbs would complete tasks faster than those students whose thumbs were taped. She address the problem in line 5 by asking, in very rapid succession, a series of questions that imply a procedural error in the group's work, asking if something made the results come out in this unexpected way? In line 7 and 11 she elaborates by first asking students to think about how they "actually conducted the experiment" and then asking them to explain to the class their process. Students here have very little role in the dialogue. For one thing, they have to parse five or six questions and figure out which one to respond to. Also, even Ms. Grant's requests for explanation become constrained. In line 11, she asks them first to explain the process, but then, before they can answer, states the first step, "you took the bottle," and then asks for the next.

Through such strategies Ms. Grant, and her colleagues, dominated the course of whole class discussions, explicitly working to guide the class to the target response or explanation, with as few detours as possible.

Research lesson: Creating an initial model

For their research lesson, Ms. Grant and her team decided to show an elapsed time video of a dead rabbit decomposing on the floor of a florist and ask students to decide which of the things they saw in the video were living or non-living. The intent was to develop a set of criteria to distinguish living, dead, and non-living things. Students watched the video clip and then wrote lists of what they saw that they considered living and non-living.

Then Ms. Grant asked students, “what is the difference between living and non-living?” She said she would write these differences on the board for all to see:

1	*Teacher:*	So I’m just going to write what you guys say what you think is living and nonliving – so can you repeat what you said again, so you said you know when something is living when –
2	*S1:*	It needs oxygen and water food and sun.
3	*Teacher:*	You said oxygen, water, food and sun. okay. Either one – if you guys have anything to share both living and nonliving. Can anybody add on to what S1 said?
4	*S2:*	Habitat?
5	*Teacher:*	For which one.
6	*S2:*	Living.
7	*Teacher:*	Okay, so habitat. What do you mean by habitat?
8	*S2:*	Um, animals need an habitat to live and stay [inaudible].
9	*Teacher:*	Okay and what about nonliving. How do we know what is nonliving?
10	*S3:*	Because it will decompose.
11	*Teacher:*	Okay so you think nonliving is something that decomposes. What else do you know? Say it again?
12	*S3:*	Doesn’t need oxygen.
13	*Teacher:*	Okay so you’re saying it’s the opposite. It does not need oxygen or doesn’t need oxygen. Can anybody else add on?
14	*S4:*	It doesn’t need anything [inaudible]?
15	*Teacher:*	When you say it doesn’t need anything ____ what do you mean by that?
16	*S4:*	Like food.
17	*Teacher:*	So you’re saying it doesn’t need oxygen. It doesn’t need food. Right? Okay what else? Can anybody add onto what did you use, how did you come up with what’s living and what’s nonliving. What was your criteria? So I know some of that is living it needs oxygen, water, sun and has a habitat, and for nonliving it decomposes and it doesn’t need oxygen or food – Marissa, did you want to add on?

For the most part, this is also a highly teacher-directed discussion, although Ms. Grant is not trying to move directly to the “right” answer. For instance, when a student says non-living things decompose, Ms. Grant did not correct him (lines 10 and 11; living things also decompose). She also, during this discussion, asked students sometimes to elaborate on their responses (T3), as in lines 3-8. The discussion continued by having students watch the video clip several more times, each time recording what they saw as living or non-living, and each time discussing the criteria they were using to make those choices.

This is certainly not a student-driven discussion characteristic of productive disciplinary engagement. Similarly to what we saw later in the spring spot observation, Ms. Grant does most of the talking and maintains control of the direction of the discussion in large part by minimizing the amount of talk from students. In contrast to the spot observation, Ms. Grant makes some efforts to elicit elaborated reasoning from students.

Conclusions and implications

The overall patterns of talk we see in our data from this second year of PD is that the teachers we work with struggle to concede control of classroom discourse to their students, thus limiting those students’ opportunities to engage in productive disciplinary discourse. While they made some effort in research lessons to incorporate discourse strategies presented in PD, it seems clear they were not appropriating those strategies as intended.

There are several interacting reasons for this, which we can discuss briefly in relation to the present analyses and earlier ones from this work.

One factor is that most of these teachers did not start with deep understandings of the practices they are trying to get their students to learn (Sandoval et al., 2016). Adding to this, most of these teachers did not seem to believe their students were capable of investigating questions or phenomena without first being told the relevant science concepts (Kawasaki et al., 2017). We were also surprised that many of these teachers did not seem well practiced in writing detailed lesson plans (Sandoval, Cournoyer, Eggleston, Modrek, & Kawasaki, 2017). Consequently, our approach of asking them to revise existing instructional units presented a difficult design and collaboration challenge, as we asked them to work together to revise an existing instructional unit. During this second year, using the storyline tool (Reiser et al., 2015) we provided, they still struggled to produce coherent sequences of instruction, particularly in articulating expansive roles for students to engage in legitimate versions of science practice (Sandoval et al., 2017b).

We draw three conclusions from this, with clear implications for professional development geared toward ambitious science teaching (Windschitl, Thompson, Braaten, & Stroupe, 2012). First, it seems clear that the radical changes to teaching practice required by the NGSS take considerable time to learn. Given that such time is not readily available for working teachers, this is a serious problem. Our own time with them is considerably more than is typical of professional development, but clearly through two years not sufficient. A second conclusion is that asking these teachers to work from their own units and import, as it were, new practices they did not yet understand well is probably asking too much. Instead, it would probably be more helpful to them to provide clear models of instructional units aligned with NGSS and, perhaps, ask them to analyze those units and what they are doing. Indeed, during our current year with them, we have relied heavily on such models and they appear, anecdotally, to be helpful. Our final conclusion is that expanding new forms of teaching practice beyond the highly supported contexts of professional development is clearly difficult. This poses a serious problem for current notions of professional development as something that teachers do, or are given, and then they are done. Our findings suggest that beyond explicit PD offerings or opportunities, teachers need workplace structures to support their ongoing learning. This is a challenge at the systemic level, and one that we, specifically, and the learning sciences generally, have not yet taken up as a problem of research. We suggest this may be a vital line of research for the learning sciences to have sustained impact on teaching practice.

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References

Banilower, E., Smith, P. S., Weiss, I. R., & Pasley, J. D. (2006). The status of k-12 science teaching in the united states: Results from a national observation survey. In D. W. Sunal & E. L. Wright (Eds.), *The impact of the state and national standards on k-12 science teaching* (pp. 83-122). Greenwich, CT: Information Age Publishing.

Berland, L. K., & Hammer, D. (2012). Framing for scientiic argumentation. *Journal of Research in Science Teaching, 49*(1), 68-94.

Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences, 15*(4), 451-498. doi:10.1207/s15327809jls1504_2

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.

Fernandez, C., & Chokshi, S. (2002). A practical guide to translating lesson study for a u.S. Setting. *Phi Delta Kappan, 84*(2), 128-134.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience.* Cambridge, MA: Harvard University Press.

Kawasaki, J., Sandoval, W. A., & Rodriguez, L. (2017). *Teachers' ideas about teaching the science practices in the next generation science standards*. Paper presented at the NARST Annual Meeting, San Antonio, TX.

Manz, E. (2014). Representing student argumentation as functionally emergent from scientific activity. *Review of Educational Research*. doi:10.3102/0034654314558490

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge, MA: Harvard University Press.

Mercer, N. (2008). Talk and the development of reasoning and understanding. *Human Development, 51*, 90-100. doi:10.1159/000113158

Michaels, S., & O'Connor, C. (2015). Conceptualizing talk moves as tools: Professional development approaches for academically productive discussion. In L. B. Resnick, C. S. C. Asterhan, & S. N. Clarke (Eds.), *Socializing intelligence through talk and dialogue* (pp. 347-362). Washington, DC: American Educational Research Assn.

Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in philosophy and education, 27*, 283-297.

NGSS Lead States. (2013). *Next generation science standards: For states, by states* (Vol. 1: The standards). Washington, DC: The National Academies Press.

Reiser, B. J., Fumagalli, M., & Novak, M. (2015). *Ngss storylines: How to construt coherent instruction sequences driven by phenomena and motiated by student questions*. Paper presented at the Illinois Science Education Conference, Tinley Park, IL.

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1), 61-94.

Sandoval, W. A., Cournoyer, N., Eggleston, N., Modrek, A., & Kawasaki, J. (2017). *Secondary teachers' struggles to create coherent ngss instruction*. Paper presented at the NARST Annual Meeting, San Antonio, TX.

Sandoval, W. A., Kawasaki, J., Cournoyer, N., & Rodriguez, L. (2016). Secondary teachers' emergent understanding of teaching science practices. In C. K. Looi, J. L. Polman, U. Cress, & P. Reimann (Eds.), *Proceedings of the Transforming learning, empowering learners: The international conference of the learning sciences (ICLS) 2016* (Vol. 2, pp. 737-744) Singapore: ISLS.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878-903.