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Teacher Responsiveness that Promotes Equity in Secondary Science Classrooms

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ABSTRACT

This study aims to deepen our understanding of teaching, specifically the role of teachers' responsiveness in promoting equity in secondary science teaching. To build a conceptual argument—that teachers' responsiveness expands the opportunity to learn for students from historically marginalized communities—I explore one high school science teacher's classroom instruction using multiple forms of data collected over 2 academic years. The teacher worked with students from Latinx, immigrant, and low-income communities. The data were analyzed focusing on both *describing* observable teaching behaviors and *interpreting* their meanings in relation to students' opportunity to learn. The analysis showed that a "responsive" teacher who expanded students' opportunity to learn attended to students' identities, historical relationships, struggles, and ideas. The teacher addressed students' relational challenges in participating in disciplinary practices at the stages of *both* planning and instruction while working against settled hierarchies, cultures, and ideologies reflected in dominant discourses. The theoretical significance and methodological complexity inherent in recognizing teachers' responsiveness for equity are discussed.

Introduction

This paper seeks to articulate the features of teachers' responsiveness that promote equity in the context of secondary science teaching. Research shows that teachers' responsiveness to diverse learners is essential in creating strong learning contexts for youth from non-dominant communities in science classrooms (Bang & Medin, 2010; Ladson-Billings, 1995; Nasir, Rosebery, Warren, & Lee, 2006). Recently, efforts have increased to study and characterize teachers' responsiveness in the context of complex classroom settings (e.g., Kang & Anderson, 2015; Russ & Luna, 2013; Thompson et al., 2016). The underlying assumption of this movement is that characterizing teachers' responsiveness will help teacher educators to facilitate professional learning in both preservice and in-service contexts, and in turn improve students' learning experiences in classrooms.

Despite growing recognition of the importance of teachers' responsiveness, the teacher education community struggles to design and facilitate professional learning that enhances teachers' responsiveness for several reasons. First, the current notion of teachers' responsiveness as a means to promote equity is under-developed and under-theorized. From sociocultural and situative perspectives (Greeno, 2006; Lave & Wenger, 1991; Wenger, 1999), every action that teachers take can be viewed as a response to a situation, including "not-responding" to certain behaviors or ideas. One cannot discern the productivity of a teacher's actions (or inaction) at a particular moment and with a particular group of students, without interpreting the *meaning*—whether and how the teacher's response facilitates student learning. Meaning-making is always situated in a

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broader historical, cultural, political, and pedagogical context and depends heavily on the learner—who the learner is and what historical experiences and relationships s/he brings into the classroom in the moment. This poses a challenge of how to recognize teachers' responsiveness for equity as part of a set of complex interactions taking place in any given moment. Furthermore, researchers generally agree that providing culturally relevant or responsive learning experiences is crucial to supporting the learning of students from non-dominant communities (Gay, 2018; Ladson-Billings, 1995). Despite being theoretically well-received, there are few empirical studies that document and unpack how teachers' in-the-moment responsiveness facilitates meaningful disciplinary learning for students from non-dominant communities, especially at the secondary level.

The goal of this study is to advance the knowledge base on the complex work of teaching, focusing specifically on teachers' responsiveness that promotes equity. Drawing upon sociocultural and situative perspectives, I examine the type and nature of responsiveness observed in a high school science teacher's classroom over 2 years. The teacher, Ms. Chadwick (pseudonym) worked at a public high school that served economically disadvantaged Latinx and Asian communities. A total of six lessons are analyzed in this paper, with a focus on the teacher's responsiveness situated in context.

This study is organized as follows: First, building upon and expanding the existing literature on responsive teaching, this study theoretically articulates the conception of teachers' responsiveness for equity as a key feature of justice- and equity-oriented teaching. Grounded in this conception, a new methodological approach to studying teachers' responsiveness is proposed. Next, I analyze classroom practices focusing specifically on a teacher's responsiveness for equity. This study concludes with a discussion of the theoretical contributions and methodological complexity inherent in recognizing teachers' responsiveness for equity *in practice*.

Teachers' responsiveness in the literature

The idea of teachers' responsiveness appears in various lines of research, including responsive teaching (e.g., Elby et al., 2014; Hammer, Goldberg, & Fargason, 2012; Robertson, Scherr, & Hammer, 2015), teacher noticing (e.g., Sherin, Jacobs, & Philipp, 2011; van Es & Sherin, 2002), formative assessment (e.g., Furtak, 2009; Furtak & Ruiz-Primo, 2008; Kang & Anderson, 2015; Shepard, 2005), and culturally responsive teaching (Gay, 2018). Grounded in the cognitive tradition of research, a majority of this literature documents teachers' responsiveness as a focus on attending and responding to student thinking (e.g., Hutchison & Hammer, 2010; Levin, Grant, & Hammer, 2012; Levin, Hammer, & Coffey, 2009; Robertson et al., 2015; Sherin et al., 2011; Thompson et al., 2016). With a strong interest in supporting the learning of disciplinary subjects, in particular science and mathematics, researchers characterize responsive teaching that promotes meaningful disciplinary learning as demonstrating the following features: (a) foregrounding the substance of student ideas, (b) recognizing disciplinary connections within student ideas, and (c) taking up and pursuing the substance of student ways of thinking (Robertson et al., 2015). From this perspective, a responsive teacher attends to the substance of student ideas manifested in either their discourse or an inscribed form of learning artifacts, recognizes the disciplinary connections within student ideas, and takes up and pursues the substance of student thinking.

There are four salient patterns emerging from this cognitive oriented research on teachers' responsiveness. First, the main source of data to study teachers' responsiveness is either a few selected segments of teaching videos wherein student ideas are present, or teachers respond to student ideas during a professional learning activity (e.g., analyzing student work, video club). Researchers analyze whether and how teachers recognize opportunities in student thinking in light of disciplinary ideas and how the teacher guides students to pursue these ideas. Typically, in this line of research, a few selected segments of lessons become the subject of inquiry in studying

teachers' responsiveness. In other words, the classroom interactions that seemingly *do not* manifest student ideas are excluded from the analysis, with the assumption that those interactions are marginally related to advancing student learning. Second, in this line of research, the analysis primarily focuses on how the teacher works both on and with *ideas*. Notably, the majority of reviewed studies provide minimal to no background information about the teacher and students as individuals (see Hammer et al., 2012 for example). Third, teachers' responsiveness as a means of promoting equity is often considered to be the fair treatment of everyone's ideas as useful resources. Instead of treating students' non-canonical ideas as wrong or misconceptions, researchers argue that teachers should listen, validate, and build upon those ideas, thus achieving "epistemic justice" (Fricker, 2007) in classrooms. A "responsive" teacher who promotes equity "makes space" for students to share and expand their ideas (Haverly, Calabrese Barton, Schwarz, & Braaten, 2020), instead of ignoring them. Finally, studies show that teachers can increase their ability to attend and respond to student thinking if they engage in well-designed professional learning activities, for example, a video club (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Cotterman & Johnson, 2013; Sherin & Han, 2004; van Es & Sherin, 2008) or collegial analysis of student work (Kazemi & Franke, 2004; Windschitl, Thompson, & Braaten, 2011). Researchers have found that teachers' responsiveness depends largely on what teachers notice in a given classroom situation, and that such noticing is primed by that individual teacher's framing (i.e., how knowledge and learning are framed in a given situation; Hutchison & Hammer, 2010; Russ & Luna, 2013; Sherin et al., 2011; van Es & Sherin, 2008).

Recently, equity-minded scholars increasingly have begun to call for broadening this conception of responsive teaching or teacher noticing within mathematics and science classrooms. Researchers challenge the cognitive focus of existing approaches while pointing to their limitations in capturing the inherent complexities of supporting students from non-dominant communities (e.g., Louie, 2018; Nasir & Hand, 2006; Rosebery, Warren, & Tucker-Raymond, 2016; van Es, Hand, & Mercado, 2017). In a case study of one mathematics teacher's responsiveness, Louie (2018) demonstrates that the teacher's noticing involves not only cognitive processes like attending to, interpreting, and determining pedagogical action, but also managing the dominant ideologies that position students—especially those from non-dominant communities—as mathematically deficient rather than as sense-makers whose ideas should form the basis for further learning. Louie argues, "the cognitive focus of existing literature obscures cultural and ideological obstacles to noticing students' mathematical thinking and strengths" (p. 56). In a study featuring four mathematics teachers who were nominated as exceptional equitable mathematics teachers, researchers van Es et al. (2017) found that these teachers attended to issues of status and positioning, individual student histories, and the energy and flow of their students and the class as a whole—the aspects of classroom activities that affect students' participation, access, and opportunity—in addition to student thinking. In the field of science education, Bang, Warren, Rosebery, and Medin (2012) highlight the settled hierarchy of knowledge, experiences, language, and ways of thinking within school science classrooms. Noting that these classroom interactions are fundamentally inter-cultural process, Rosebery et al. (2016) argue that a key for engaging in equitable science teaching is increasing teachers' "interpretive power" (p. 1573). With this enhanced interpretive power, teachers can see and interpret classroom situations in a far more complex way.

In short, there is a general consensus among researchers that responsiveness or responsive teaching involves teachers attending to, interpreting, and determining pedagogical actions. Whereas the existing body of literature on responsive teaching primarily focuses on teachers' work on student ideas or thinking, scholars who draw upon sociocultural or critical perspectives demonstrate that teacher noticing is tightly related to culture, ideology, and power dynamics in a particular context, which in turn shape their instructional practices (Louie, 2018; Nasir & Hand, 2006; van Es et al., 2017).

Teachers' responsiveness for equity: expanding opportunity to learn

My inquiry into teachers' responsiveness for equity rests on one premise: The forms of teachers' responsiveness that promote equity are those that facilitate meaningful disciplinary learning for students who have been historically marginalized in classrooms—students of color and those from linguistically and socioeconomically disadvantaged communities. In building upon and expanding the existing body of literature on this topic, I theorize that teachers' responsiveness for equity consists of three dimensions: (a) a teacher's attention to students' needs or struggles, in addition to their contributions as members of a larger classroom learning community; (b) a teacher's interpretation of classroom situations with consideration of race, power, and opportunity to learn, and (c) a teacher's taking of pedagogical actions that expand students' opportunity to learn in classrooms. In my conception of responsiveness for equity, "action taking" is central because it is the actions taken that make an observable difference in students' experiences in classrooms. In the following, I first unpack the relationship between teachers' actions and students' opportunity to learn. Then, I discuss how pedagogical actions are shaped by the things that teachers attend to and interpret—teacher noticing.

Taking pedagogical actions that expand students' opportunity to learn

The classroom is a complex activity system (Greeno, 2006; Lave, 1988; Lave & Wenger, 1991). Activity system here refers to "complex social organizations containing learners, teachers, curriculum materials, software tools, and the physical environment" (Greeno, 2006, p. 79). In any given moment, multiple components of activity systems play out together to dynamically and relationally create the conditions for learners' participation in the classroom learning community. By "dynamically," I mean that the conditions for learners' participation are constantly shaped and re-shaped through interactions among the various components of activity systems. By "relationally," I note that activity systems in the classroom have different affordances for different learners depending on their historical and current relationships with people, the discipline, and the physical setting (e.g., school, science classroom). From a sociocultural and situative perspective, learning is viewed as changing learners' participation in practice in a way that is valued by the community (Greeno, 2006; Greeno & Gresalfi, 2008). The *affordances* (coined by Gibson, 1977, 1979; see also Gee, 2008) of activity systems for changing a particular learner's participation in the community is conceived of as the learner's *opportunity to learn* (OTL; Gee, 2008; Greeno & Gresalfi, 2008). The classroom teacher, who is one key component of the activity system, can influence students' OTL by changing the characteristics of that system. For example, a "task"—one component of the activity system—can be modified so that it provides personal meaning to a particular group of students or their families, which can increase the affordances for students' participation in disciplinary practices. Providing sincere affirmation and encouragement (e.g., "You are on the right track. You can do this.") for a shy girl from an immigrant, low-income, Spanish-speaking family, who has been placed in lower-track classes at school, can increase the affordances for that girl to participate in disciplinary practices in the moment by enhancing her sense of belonging and aptitude. Drawing students' attention to the racial injustice and structural inequity that manifest in their daily lives and connecting these ideas to a given academic task can increase the affordances for students' participation in disciplinary activities by enhancing their agency to "make a difference" or "make a better world" through the learning of the subject. From sociocultural and situative perspectives, the relationship between a teacher's pedagogical actions and student learning is neither straightforward nor linear. Rather, a teacher's pedagogical actions *mediate* student learning by helping improve *conditions* for particular students' interactions with a particular group of people and informational resources in the classroom learning community. In theory, a teacher's pedagogical actions that promote equity are those that

increase historically marginalized students' OTL—altering affordances within the activity system by changing the conditions of that system in the moment.

Attending and interpreting

A teacher's pedagogical actions are deeply related to what a teacher attends to and how they interpret the things they notice (e.g., van Es et al., 2017). This work of noticing is not only influenced by each individual teacher's framing about knowledge and disciplinary learning, but also the culture, ideologies, and even social relationships and memberships that the teacher holds in a particular time and place (Kang & Anderson, 2015; Louie, 2018). Researchers have found that those teachers who successfully support historically marginalized students in disciplinary classrooms attend to a wide range of things (van Es et al., 2017). Not only do these teachers attend to students' contributions to the academic activity, but also the needs or struggles stemming from factors in students' homes and community environments (Gay, 2018; Ladson-Billings, 2009; Wallace & Brand, 2012). These teachers interpret what they have noticed in a unique historical and political context, and advocate for students' well-being as well as academic success. This idea is illustrated in work by Wallace and Brand (2012) that analyzes the practices of two middle school science teachers deemed culturally responsive educators using critical race theory. Both teachers were considered "effective" in supporting African American students in their classrooms. These researchers propose key characteristics of the two culturally responsive teachers' pedagogical actions based on an analysis of a conversation with the two teachers:

> Both teachers' conversations primarily emphasized their concern for their students as individuals, referencing needs stemming from factors in their home and community environments. These teachers were aware of how circumstances in their students' lives could impact their performance and achievement, and sought to foster an atmosphere that was preemptive. This concern for their students translated into advocacy; actual expressions of the teachers' ownership of their responsibility to accommodate students' needs in the classroom. These middle school science teachers consider it their responsibility to remove or alleviate environmental factors that would prohibit their African American students' achievement, beyond the mere acknowledgement of their life conditions. This ownership appeared to be driven by an understanding of the impact of social inequities on their African American students' lives, otherwise known as sociocultural awareness. (p. 354)

Prior studies examining teachers who successfully support their historically marginalized students also note teachers' deep relationship with and care about their students (e.g., Ladson-Billings, 2009). Currently, however, there are few studies that examine how a teacher's attention to his/her students' need or struggles based in circumstances *outside* the classroom shape teachers' *in-the-moment* pedagogical actions, beyond documenting teachers' reflection. There are few empirical studies that show how a teacher's pedagogical actions affect marginalized students' OTL.

Recognizing teachers' responsiveness that promotes equity

My conceptualization of teachers' responsiveness that promotes equity points to three methodological issues that need to be considered carefully. These issues have to do with: (a) the source of data, (b) the unit of analysis, and (c) analytical processes.

First, the conception of teachers' responsiveness grounded in sociocultural perspectives calls for *using various sources of data that provide rich contextual and personal information of the actors (i.e., teacher and students) in classroom settings* in order to recognize teachers' responsiveness for equity. Using rich contextual information is essential to generate the meanings of a teacher's actions at any moment—whether and how the system of activities altered by a teacher's pedagogical actions improves the conditions for a particular group's meaningful participation in

the classroom learning community in a particular moment. Prior studies grounded in the cognitive research tradition tend to examine 'responsive' teaching or a teacher's responsiveness relying mostly on the observational data that captures in-the-moment interactions (e.g., video). Notably, many prior studies on responsive teaching pay little attention to learners' identities or histories, beyond the ideas or thinking expressed by the learner in the moment. This approach is limited to recognize whether and how a teacher's pedagogical actions contribute to increase students' opportunity to learn that is *relationally* co-constructed through the interactions and historical relationships among learners and the teacher (see Maskiewicz & Winters, 2012).

Second, the conception of teachers' responsiveness proposed in this study calls for *shifting the unit of analysis from individuals to activity systems* (see Greeno, 2006). One key issue in studying teaching is deciding the unit of analysis—how to cut classroom interactions in a lesson, and which part of the interactions should be the focus of analysis. Prior studies tend to analyze only a few selected segments of observational data capturing the specific classroom interactions in which researchers are interested (e.g., a segment where teachers attend and respond to student thinking). Analysis tends to focus on examining any desirable changes within the segments using individuals as a unit of analysis. From sociocultural perspectives, any actions taken by a teacher are in response to the classroom situations, and those actions *can* affect the conditions informing students' participation in disciplinary practices by changing the characteristics of the activity systems. This is exemplified by an interaction observed in the present study, between the teacher and a group of students, including a recent immigrant student Huy, in the context of a small group activity. The teacher visited the table, sitting down and introducing Huy to the other group members saying, "Hi! This is Huy from Vietnam." The teacher thus facilitated students' relationship-building while highlighting personal backgrounds, experiences, and strengths of a specific student, and then initiated the conversation about how to work together to complete the small group task despite a linguistic challenge. Although this set of interactions does not include any disciplinary ideas, such interactions affect students' OTL by changing the *relationships* in-the-moment among the students at that table. In order to understand whether and how these pedagogical actions contribute to improving students' OTL, analysis should be conducted at the level of the activity system with careful attention to any change in its components (e.g., task design, role and relationships among actors, tool use), beyond analyzing changes in individuals' thinking. Any pedagogical action that alters the *conditions* for students' participation throughout a lesson need to be attended to and analyzed in a principled way.

Finally, in order to characterize teachers' pedagogical actions that promote equity, researchers must pay balanced attention to both describing observable teaching behaviors and interpreting their meanings in relation to students' OTL. Describing observed teaching behaviors involves two analytic processes: describing (a) what a teacher attends to during the interactions with students, and (b) what pedagogical actions the teacher takes in response to the situation (Kang & Anderson, 2015). Interpreting the meanings of teachers' pedagogical actions involves two additional analytic processes: (c) examining whether and how the characteristics of activity systems are changed by the teacher's pedagogical actions, and (d) examining whether and to what extent the modified activity systems improve the conditions for students' participation in the classroom learning community in the moment.

Research questions

The purpose of the present investigation is to explore teachers' responsiveness as a means of promoting equity *in practice*. Within this framework, the following questions guided the analysis:

1. What did the teacher attend to while working with students who have been historically marginalized in science classrooms? What pedagogical actions did the teacher take in response to each situation?

2. Whether and how were the characteristics of the activity system changed through the teacher's pedagogical actions? Whether and to what extent did the modified activity systems improve the conditions for students' participation in the classroom learning community in the moment?

Method

This study employs a qualitative case study approach (Merriam, 2009; Yin, 2013) to explore teachers' responsiveness that promotes equity as situated in contexts.

Participant and context

This study is part of a larger project examining novice secondary science teachers' learning trajectories. Data for this study were collected over 2 years in 2015–2017, during the participants' 1st and 2nd years of teaching. All the participants were enrolled in science teaching methods courses taught by the author during their preparation period. For this particular study, one case study teacher, Ms. Chadwick was selected for three reasons. First, the researcher had access to the rich data that enabled the researcher to explore the teacher's pedagogical actions, reasoning, and interactions with students in contexts based on a long-term relationship (Yin, 2013). The access to this rich information was crucial to examine whether and how the teacher attended to students' identities and historical relationships. Second, this case study teacher showed deep care, empathy, and advocacy for her students, all characteristics identified by prior studies as features of equity-minded educators (see Ladson-Billings, 2009 for example). Ms. Chadwick is a White female who grew up in a working-class family and experienced various family-related struggles during her adolescent years. After completing college, Ms. Chadwick worked at an online tutoring company, and decided to be a science teacher because she wanted to share her love of science with others. Ms. Chadwick viewed learning science as "being critical of everything and wondering about things and how they work and why they work." Ms. Chadwick considered being critical an essential skill as a citizen who encounters science- and technology-related issues on a daily basis and has a right to vote. Therefore, for Ms. Chadwick, "It's a huge disservice to any kid, any adult to not be strong in [this] ability." Finally, the case of Ms. Chadwick was selected because of the school context and identities and backgrounds of the students in her classrooms. Ms. Chadwick taught College Prep Chemistry and Life Science courses at a public high school located in a predominantly low-income, Latinx community in Southern California. About 77.5% of students in this school were Hispanic or Latinx, 14.2% were multilingual, and 68.3% were eligible for free/reduced lunch. Student demographic differed substantially between upper and lower track science courses. For example, over 90% of students in Ms. Chadwick's Life Science class (a lower-track course) were Latinx and multilingual students.

It is important to note that Ms. Chadwick played an active role in the study, beyond supporting the researcher's data collection. Not only did she provide rich information about students and contexts, but she also helped to generate the meanings of observed classroom interactions by providing her perspectives on the researcher's interpretations during the data analysis.

Data generation

Multiple forms of data were generated through observation, interview, and artifact collection over 2 years.

Observation

A total of six lessons were observed by the author and a research assistant present in the teacher's classroom (i.e., three lessons per year). Observations were conducted at the teacher's invitation. The teacher invited us when she engaged students in conversation about a lab or hands-on activity. All lessons were videotaped. Typically, the recording began approximately 1–5 minutes prior to the bell in order to capture the teacher's very first interactions with students. The recording ended when all students left the room, typically 2–3 minutes after the bell. In addition to the video recordings, the researcher produced about 10–14 pages of detailed field notes during each visit.

Interview

A total of six semi-structured, post-observation interviews were conducted immediately following the observations. The interviews took place in the teacher's classroom for approximately 40–50 minutes. This conversation focused on understanding the lesson context as well as the teacher's pedagogical reasoning behind their actions during instruction. For example, the researcher asked, "How and why did you design this lesson in this way? Which curriculum did you use and why?" "I noticed you … [description of the teacher's interaction with student]. Could you tell me about this?" In addition, the researcher conducted an interview at the end of each year (a total of two end-of-year interviews). These end-of-year interviews focused on understanding the context around teaching, such as school and department culture, curricular resources, characteristics of student population, parents, and the local community.

Artifact collection

The researcher collected various artifacts of teaching and student learning, including curriculum materials, instructional slides, and samples of student work. These data were used to triangulate the teacher's pedagogical reasoning and actions. The researcher also took pictures during the visit to document the classroom setting and any changing configurations among the teacher and students during instruction. These photos were used as a complementary source of data.

Data analysis

Guided by the framework, the analysis first sought to describe teachers' attention and pedagogical actions during instruction (research question [RQ1]). Next, the research team conducted the in-depth qualitative analysis to examine whether and how the teacher's pedagogical actions improve students' OTL (RQ2). The following describes each in detail.

Describing teachers' attention and pedagogical actions (RQ1)

Three researchers (i.e., the author and two research assistants) participated in the data analysis. We first generated video-logs that chronically described the main topics, actors, and activities from each lesson, and transcribed the post-observation interviews. The video-log of each lesson was chunked into teaching episodes (e.g., warm-up, launch of the task, small group work, whole group discussion), and later into events (i.e., the units of analysis). The video-log helped us to understand the overall flow of the lesson, which was essential in interpreting the meaning of in-the-moment interactions.

Defining events as the unit of analysis. Guided by the theoretical framework, the unit of analysis for video-recorded lessons was defined as an event. An event was a set of exchanges observed during instruction with the following characteristics: (a) substantial exchanges about *the*

same topic among a group of *the same actors*, including the teacher, and (b) verbal or non-verbal actions by teacher attending to *and* addressing a particular problem in-the-moment for either an individual or the collective. The interaction was considered complete if the topic of conversation shifted or if the actors were changed via movement of the teacher or students. A total of 638 events were identified from 6 lessons (a total of 371 minutes long videos). On average, the length of one event was 35 seconds.

In addition, the researchers identified a total of 51 events from the post-observation interview transcripts. An event from an interview transcript referred to an account that included both a problem noticed by the teacher and a description of the teacher's pedagogical actions to address that problem. Unlike the events identified from teaching videos, events from interview transcripts represented a teacher's self-described actions (e.g., what the teacher did before, during, or after a lesson). Students were not physically present in events, although they were the driver of the teacher's actions.

Coding the teacher's attention and pedagogical actions observed in teaching videos. The research team coded each of the 638 events focusing on the following questions: (a) what problem or challenge did the teacher attend to during the interactions with students? and (b) what pedagogical actions did the teacher take to address the challenge? The coding scheme was developed iteratively over 14 months while developing the framework and examining the data. Data were coded using the final coding scheme. Any disagreement was discussed in weekly meetings until all three researchers reached consensus.

In the final coding scheme (see Table 1), the things that the teacher attended to and addressed in each event were categorized as three types of challenges expressed by students: (a) intellectual ($n = 438$ out of 638, 68.7%), (b) relational ($n = 427$ out of 638, 66.9%), and (c) linguistic challenges ($n = 10$, 1.7%). We identified 12, eight, and three pedagogical actions taken by the teacher to address each of the challenges, respectively. *Intellectual challenge* referred to any ideas, confusion, or difficulties expressed by students in deepening their conceptual understanding. In one event observed in Ms. Chadwick's chemistry lesson on stoichiometry, for example, students were tasked with investigating a way to make safe air bags for baby strollers "without wasting any chemicals" while filling the maximum capacity of the bag. They were given a total of 45 g of sodium bicarbonate and some vinegar (a 5% acetic acid solution). When Ms. Chadwick moved to one lab table, a group of four students were in the middle of their experimentation. Ms. Chadwick noticed that the students missed the "leftover" sodium bicarbonate that had not reacted, which was critical to figure out the appropriate amounts of reactants—the key idea of stoichiometry.

Ms. Chadwick: [takes the bag and holds it up slightly so everyone in the group can see] Well, what do you have extra of? Is it done?

S1: Yeah.

S2: I think so.

Ms. Chadwick: [Small pause before holding the bag up higher] Is there chemical reaction still happening? [shakes the bag a little]

S1: Kinda?

Ms. Chadwick: [Looks at S1] What evidence you have that there's still reaction happening?

S1: [Presses the bag slightly while Ms. Chadwick is still holding it up] It is (pauses) fizzing?

Ms. Chadwick: There are still bubbles, yeah. So maybe a little bit, [sets the bag down] but what do you see that's extra?

S1: Baking soda!

Table 1. Coding scheme: teacher responsiveness in teaching videos (total number of events = 638).

What to attend	The type and nature of pedagogical actions ("How" to respond)	Frequency
Intellectual : any ideas, confusions or difficulties expressed by students in deepening their conceptual understanding *A total of 438 out of 638 events (68.7%)*	• Drawing students' attention to key information or pattern	198 (*45.2)
	• Reminding the goals and directions for the task to reengage students who encountered a challenge	175 (40.0)
	• Asking probing questions that either problematize students' ideas or guides thought process	157 (35.8)
	• Re-voicing/re-stating to help students see the problem space in a new way	84 (19.2)
	• Leveraging one student's ideas to expand the class's understanding (typically during the whole group discussion)	72 (16.4)
	• Connect, compare, stitch students' ideas to build upon collective understanding	71 (16.2)
	• Provide factual information directly to clarify the confusion	66 (15.1)
	• Adjusting task (e.g., expanding time, adding scaffold, adding new observation) or providing alternatives in order to prevent students' missing experiences	59 (13.5)
	• Checking work and giving some sort of "okay" to give students confidence in progressing their work	42 (9.6)
	• Connecting to prior units or prior lesson [school knowledge] as a resource to solve the current problem (typically during one-on-one conversation)	38 (8.7)
	• Connecting to everyday experience as a resource to solve the current problem; either individually or as a group	37 (8.4)
	• Changing the participation structure (e.g., from individual presentation to a whole group discussion) on-the-fly to build upon student ideas, typically for a whole group discussion	24 (5.5)
Relational : difficulties or struggles in relating him or herself to the discipline, people, and/or the place (i.e., science classroom or school) *A total of 427 out of 638 events (66.9%)*	• Reminding norms and rules of behaviors to create a supportive learning environment	152 (**35.6)
	• Emotionally encouraging/reassuring the good progress to motivate students	143 (33.5)
	• Leveraging students' interest to modify the task on the fly to help students see themselves in the work	78 (18.3)
	• Providing either material or emotional support to validate students' wellness in the moment	74 (17.3)
	• Showing appreciation to validate what they do and who they are	61(14.3)
	• Talking about student's life outside the school to affirm student's good decision	16 (3.7)
	• Connecting a struggling student with a friend to help	12 (2.8)
	• Using students' vernacular to encourage students' participation in academic task	8 (1.9)
Linguistic : any difficulties or struggles in using languages that mediate the learning of discipline *A total of 10 out of 638 events (1.6%)*	• Adjust task to student's capabilities and needs on the linguistic level	5 (***50.0)
	• Paring the ELs with a friend who can help (translate)	3 (30.0)
	• Connecting to everyday language/experiences to help students to generate meaning of the academic language	3 (30.0)

*This is the relative percentage of each pedagogical action undertaken by the teacher to address students' **intellectual** challenge. For example, 198 out of 438 events where the teacher attended to intellectual challenge, the teacher responded to the situations by "drawing students" attention to key information or pattern (e.g., (198/438) × 100 = 45.2%).

This is the relative percentage of each pedagogical action undertaken by the teacher to address students' **relational challenges. For example, 152 out of 427 events where the teacher attended to relational challenge, the teacher responded to the situations by "Reminding norms and rules of behaviors to create a supportive learning environment" (e.g., (152/427) × 100 = 35.6%).

***This is the relative percentage of each pedagogical action undertaken by the teacher to address **linguistic** challenge. For example, 5 out of 10 events where the teacher attended to relational challenge, the teacher responded to the situations by "Adjust task to student's capabilities and needs on the linguistic level" (e.g., (5/10) × 100 = 50.0%).

Ms. Chadwick: So, what is your trial 2 gonna be?

S1: More vinegar.

S2: [at the same time] Less baking soda? [then after S1, but speaking softly] More vinegar.

Ms. Chadwick: Mhmk. [looking down on the table at their paper] Figure it out and go on. Just release the air and then you'll trash the baggie [walks away].

S1: Cool, cool.

During this short interaction, Ms. Chadwick drew students' attention to a key observation (e.g., bubbling, fizzing) by asking, "What evidence [do] you have that there's still [a] reaction happening?" Ms. Chadwick's pedagogical actions was coded as *drawing students' attention to key information or patterns* ("how" code). Among 638 events, a total of 438 events (68.7%) were coded as attending and addressing intellectual challenge. The research team identified 12 pedagogical actions ("how") undertaken by the teacher to address students' intellectual challenge (see Table 1).

Relational challenge referred to students' difficulties or struggles in personally relating to the discipline, people, and/or the place (i.e., science classroom or school). Relational challenge manifested as emotional expressions, gestures, patterns of participation, or behaviors (e.g., frustration, excitement, being quiet, not completing the task). In one event observed in Ms. Chadwick's lesson on sensory organs and the nervous system, she noticed that a few boys were socializing with each other instead of working on the task. When she approached their table, the boys told Ms. Chadwick that the question was too difficult:

Ms. Chadwick: Okay. [think for a second] What's your favourite sport?

Boy 1: Football

Boy 2: Soccer

Ms. Chadwick: Soccer?

Boy 2: Yeah

Ms. Chadwick: So we're gonna go with soccer. [class mumbling] Shhhhh. I want you guys to explain to me how the nervous system is used, by the goalie-

Boy 3: Reflexes

Ms. Chadwick: I want you, shhh, explain to me what is going on with the nervous system for a goalie to block a shot at goal at soccer, during a soccer game? If they miss, shhh, tell me why they would miss? If they get it, tell me why-

Boy 3: They're awesome!

Ms. Chadwick: Tell me why they're awesome? Does that make sense? Tell me how the nervous system is used, for a goalie to block a shot on goal during a soccer game? You are welcomed to draw a picture.

In this event, Ms. Chadwick addressed students' difficulties in connecting themselves to the academic task in the moment by *leveraging students' interest and modifying the task on the fly* ("how" code). Re-contextualizing the task using a favorite sport facilitated students to see themselves in the work, therefore engaging them, as evident from the work the student produced (see the Figure 1). Overall, about 67% of events were coded as relational challenges (427 out of 638 events, 66.9%). When students expressed more than one kind of challenge, those events were double coded to capture the multi-faceted nature of responsiveness. In this dataset, the research team identified a total of eight pedagogical actions undertaken by the teacher to address the relational challenge ("how" to respond; see Table 1).

Linguistic challenge referred to any difficulties expressed by students in using language to mediate the learning of the discipline. Linguistic challenges were particularly salient when

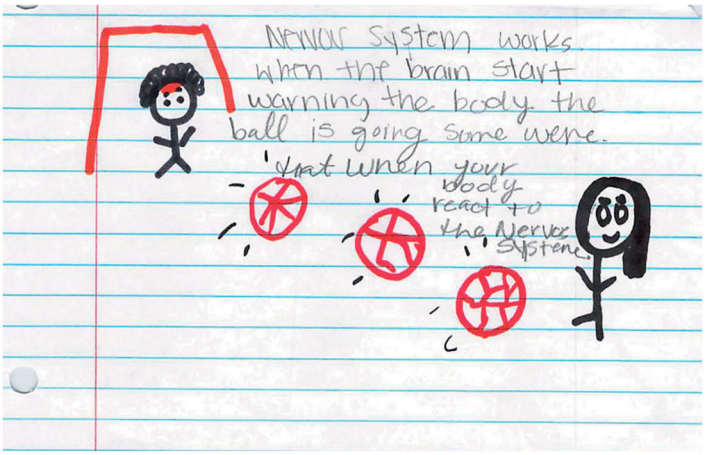

Figure 1. A learning artifact (an exit ticket) produced from the lesson.

multilingual students participated in English-privileged learning environments. In a lesson observed in the Life Science class, for example, students were learning about the structure and function of sensory organs in the human body. Students as a small group were asked to discuss and summarize the prior day's lab results on a poster. Ms. Chadwick asked students to close their laptops and fully engage in the work as a group. In this class there was a Vietnamese girl, Tien, who had recently moved to the United States and did not speak English at all. In one event, Ms. Chadwick moved to Tien's group and said, "Can one of you guys get out the laptop and Google Translate? You can communicate with that." The students were unsure of how to include Tien's ideas in their poster. Ms. Chadwick guided this group work, including Tien:

> "So you're just gonna have to pass notes, but she [another Vietnamese girl] can help you write sentences. She can help you write-um-Google Translate. So she can tell you what Tien's ideas are, and then translate them, and then you guys can put them on. Does that make sense?"

Here, Ms. Chadwick *modified the task design* for this particular group to address Tien's difficulties stemming from the use of language so that Tien could contribute intellectually to the group's poster. In addition to attending to and addressing Tien's *linguistic* challenge, Ms. Chadwick also attended to and addressed Tien's *relational* challenge by providing emotional support. Ms. Chadwick said, "You guys know how it feels like not be able to talk a group of people, right?" Students responded, "Yeah!" Before Ms. Chadwick left the table, she told Tien, "Now it's *just* language. It'll be okay." Out of 638 events, there were 10 in which Ms. Chadwick noticed and addressed language-related difficulties expressed by multilingual students, all of which occurred during the two Life Science lessons. As illustrated in the above example, linguistic challenges were often coupled with relational ones. The research team found three pedagogical actions that addressed linguistic challenges ("how") in this dataset (see Table 1).

Coding the type and nature of teachers' responsiveness observed in interview transcripts. A total of 51 events from interview transcripts were also coded using a similar approach. Whereas the events in teaching videos were analyzed with a focus on the subject of responsiveness (i.e., what the teacher attended to) and the types of pedagogical action, one additional characteristics of responsiveness emerged in the analysis of interview transcripts—the timing of the responsiveness ("when").

In terms of the problem or challenges attended by the teacher, the researchers found one additional learning challenge from the interview transcripts: home and family-related learning

Table 2. Coding scheme: teacher responsiveness in interview transcripts (total number of events = 51).

Dimensions	Codes	Frequency
Subject of response (about "What")	• Intellectual challenge	39 (*76.5)
	• Relational challenge	17 (33.3)
	• Linguistic challenge	5 (9.8)
	• Home and family related challenge	2 (3.9)
Types of pedagogical actions ("How")	• Modifying task design	28 (**54.9)
	• Adding, removing or changing the use of tools or scaffolds	12 (23.5)
	• Modifying the type and nature of talk move and/or questions	4 (7.8)
	• Adjusting norms and expectations of what is okay and appropriate in their classrooms	4 (7.8)
	• Modifying participation structure	3 (5.9)
Timing of actions ("When")	• In-the-moment responsiveness	21 (***41.2)
	• Lesson level responsiveness	16 (31.4)
	• Unit level responsiveness	17 (33.3)

*This is the relative percentage of each subject of response. For example, in 39 out of 51 events the teacher attended to intellectual challenge (e.g., (39/51) × 100 = 76.5%).

**This is the relative percentage of each type of pedagogical actions. For example, in 28 out of 51 events the teacher modified task design to address students' challenge (e.g., (28/51) × 100 = 54.9%).

***This is the relative percentage of each level of pedagogical actions. For example, in 21 out of 51 events the teacher described the actions to address challenges in the moment of interactions (e.g., (21/51) × 100 = 41.2%).

challenges (see Table 2). For example, Ms. Chadwick had to adjust her homework policies to address students' struggles stemming from home or family-related situations. In one event, Ms. Chadwick stated, "most of [my students] either have a job or siblings or something, they don't do homework pretty much. It would be detrimental to their grades if I give a lot of homework to them. So, I try to give them as much time as possible to get things done in class."

In terms of pedagogical actions, the teacher typically described her pedagogical actions broadly during the interviews (see Table 2). The pedagogical actions were categorized as belonging to one of the five groups, reflecting the components of the activity systems: (a) modifying task design ($n = 28$ out of 51 events, 54.9%), (b) adding, removing, or changing the use of tools or scaffolds ($n = 12$, 23.5%), (c) modifying the type and nature of talk move, and/or questions ($n = 4$, 7.8%), (d) adjusting norms and expectations of what is appropriate in their classrooms ($n = 4$, 7.8%), and (e) modifying participation structure ($n = 3$, 5.9%).

Whereas analysis of the teaching videos allowed the researchers to capture in-the-moment responsiveness during instruction, analysis of the interview transcripts revealed multiple moments throughout the unit or even the academic year in which the teacher took deliberate action to improve the conditions of students' academic success. In the final coding, the timing of the responsiveness was categorized as: (a) in-the-moment responsiveness, (b) lesson-level responsiveness, and (c) unit-level responsiveness. *Lesson-level responsiveness* referred to modifying some aspects of lesson design to address students' difficulties noted from a prior lesson ($n = 16$ out of 51 events, 31.4%). During a post-observation interview, Ms. Chadwick described her students' difficulties in linking academic vocabulary (e.g., "viscosity") to observation or experiences ("thicker or thickness"). She modified the lesson design by adding a discussion to address this difficulty (code = *intellectual challenge, modifying task design*). *Unit-level responsiveness* referred to pedagogical actions modifying the unit design, such as selecting the focal phenomenon in response to students' interest and experiences or modifying the format of assessment from multiple choice to constructing explanations ($n = 17$ out of 51 events, 33.3%).

Recognizing teacher's responsiveness that promotes equity: analyzing students' opportunity to learn (RQ2)

Following the analysis of 689 events (638 from teaching videos, 51 from interview transcripts), the research team conducted in-depth qualitative analysis of a select number of "positioning events" to examine whether and how the teacher's pedagogical actions improved the OTL of students who have historically marginalized in science classrooms. *Positioning events* referred to the events that included: (a) the teacher's interactions with students from non-dominant communities, and (b) the teacher's pedagogical actions in response to her students' nontraditional forms of thinking, talking, doing or being in science classrooms, or any challenge students expressed to their participation in disciplinary practices. The underlying assumption was that those events served as a window into the complex pedagogical work in a given moment—whether and how the teacher attended to and addressed the identities and historical experiences of a student, whether and how the teacher addressed epistemic injustice in the moment, and whether and how the teacher interpreted the situation in a complex way by locating the people and observed behaviors in a thick context.

Among 638 events from six teaching videos, a total of 68 positioning events were identified and transcribed. These positioning events were analyzed focusing on any change of students' OTL mediated by the teacher's pedagogical actions. Specifically, the researchers examined whether and how the characteristics of activity systems was changed through the teacher's pedagogical actions. The researchers also considered whether there was any change in students' patterns of participation before and after these interactions with the teacher. Students' enhanced participation was used as an indicator of the enhancement of the conditions for students' participation in disciplinary practices—improving OTL. In addition to the analysis of each positioning event, the meanings of the teacher's in-the-moment actions were examined holistically, beyond the boundary of each positioning event, while looking at the patterns across the events over time and who the student is. The meanings of the teacher's pedagogical actions were first interpreted by the researchers, and then reviewed by and discussed with Ms. Chadwick while drafting the manuscript. Ms. Chadwick offered nuance in this process while providing additional information, such as stories about students and contexts.

Findings

This section illustrates some key features of teachers' responsiveness that expanded students' opportunity to learn (OTL) using one lesson. In this focal lesson, the research team identified a total of 123 events from the teaching video (60 minutes), and 8 events from the post-observation interview (57 minutes). Out of 123 events identified in the video, about three quarters were coded as relational ($n = 91$ events, 74.0%), over half of the events as intellectual ($n = 75$ events, 60.9%), and three were coded as linguistic challenges (2.4%). In other words, a major part of teaching in this lesson had to do with attending to and addressing students' struggles in relating themselves to the people, academic tasks or the space. About one third of events (37%, 46 out of 123) were coded as both intellectual and relational, suggesting that the teacher attended to and addressed multiple challenges simultaneously to engage students in disciplinary practices. Out of 123 events, 22 positioning events were further analyzed focusing on the relationship between teacher's pedagogical actions and the students' OTL.

In the following, I first present the context of school and students in this class. Next, I describe the teacher's pedagogical actions and reasoning behind the design of the lesson. Finally, I illustrate in-the moment of interactions throughout the lesson. I pay particular attention to one student to show how the teacher's pedagogical actions expanded this student's OTL.

The school, students, and classroom settings

The focal lesson was observed in Ms. Chadwick's 10th grade Life Science class. Life Science was offered to students who were deemed unsuccessful in both their eighth and ninth grade science classes. In eighth grade, these students were predicted by their teachers to be unlikely to succeed in College Prep (CP) Biology or Honors Biology in their ninth grade year, and thus were placed into a ninth grade, low-track Earth Science course. Students who then failed Earth Science as well were tracked into 10th grade Life Science. This class was often referred to among the other science teachers in the department as "a throw away class," "the lowest [of] the low."

In the focal lesson, a total of 22 students were sitting around the room in groups of two to four. The majority of students were from immigrant Mexican families. There was only one White boy, Jack [all names are pseudonyms], who had missed the last few days of school. There was one African American boy, Brian. Brian was the fifth son in his family, lived in poverty, and had an individual education plan (IEP). Two Mexican girls, who were sitting away from each other, just returned to the classroom from five days of suspension following a big fight. Twenty of the students ($n = 20$; 90.9%) in the class were multilingual. There were a range of English proficiency in this class, including two recent immigrant students, Tien and Victor. Tien was a Vietnamese girl who moved to the United States a few weeks ago, speaking no English at the time of this study. The other boy, Victor, was from Guatemala, having immigrated to the United States a few months prior. Several boys in this class, including Marcello and Carlos, had been involved in gang activity. Many students in this class lived in poverty and had difficult lives outside of school, some working over 15 hours per week or caring for siblings. Many students in this class were used to failing school, planned to attend the continuation high school later in the year, and were not motivated by grades.

The teacher's responsiveness during the planning: fighting against the negativity, low expectations, and prevalent instructional culture

Ms. Chadwick constantly heard negative discourse from colleagues regarding the students enrolled in the Life Science class. For example, some teachers said, "Oh, the Life Science kids are gonna be in Bio next year … we're gonna have to lower the bar." Planning lessons was a constant battle for Ms. Chadwick. She had to decide "what you can and cannot attack right now, like what did [she] value the most that [she] was unwilling to compromise on right now, and what … to wait on because [she] could not possibly survive and do everything the way [she] wanted to." The teaching materials recommended by her department focused on rote-memorization of target vocabulary and multiple-choice assessment. Ms. Chadwick thought, "some of the people in the department don't necessarily appreciate what [the Life Science students] are accomplishing because it doesn't look … typical." Ms. Chadwick felt it was important to "make sure that the kids are learning in [her] class."

Instead of teaching through rote-memorization tasks and multiple-choice assessments, Ms. Chadwick decided to teach "asking questions and thinking about things." She also decided to change the assessment format from multiple-choice to constructing written or verbal explanations. She thought that teaching students to ask questions and think about things would "make them more successful in their class next year." Supporting the kind of science learning that she valued meant *not* being responsive to certain expectations held by her colleagues and administration. For example, she decided to give up pursuit of a good evaluation score by the school administrator. Ms. Chadwick learned that her values for classroom organization and pedagogical action were "not necessarily what the discipline in admin wants to see." She was marked "off for evals" in the category of classroom management, but she decided to let it go. She said, "I'm willing to have chaos … It's okay."

The focal lesson was observed on May 26, 2016, near the end of Ms. Chadwick's first year, about 2 months before the 2016 Brazil Summer Olympics. Given the outbreak of the Zika virus around that time, preventing the spread of the virus during the Olympic Games was a big issue. Ms. Chadwick's students, who were interested in the upcoming Olympics, were curious about Zika virus. Ms. Chadwick said, "My students asked me, 'Ms. Chadwick, what's the Zika virus? How does it work?' A total of four different students per class asked about it." Since Ms. Chadwick had to teach health standards near the end of the year, she decided to use the example of the Zika virus in the upcoming Olympics to teach the unit on infectious disease (code = *unit-level responsiveness, modify the task*). The question that guided the unit was, "How to prevent the spread of Zika virus through the Olympics?" The final project of this unit was to either make a suggestion to the World Health Organization or propose a plan for handling the spread of Zika virus.

During the first 1.5 weeks, students explored disease transmission using the Ebola as an example. Ms. Chadwick asked students to figure out what they would do to keep Ebola from spreading to other people. From students' conversations, Ms. Chadwick noticed that students did not know the differences between viruses and bacteria, which was essential knowledge to figuring out how to prevent the spread of Zika virus in the upcoming Olympics. Therefore, she changed her plan in the middle of the unit and decided to address this idea. Ms. Chadwick said, "What they've learned about in middle school about bacteria and viruses has not stuck, so it's kind of a remedial. That's [how] my entire unit changed when I realized that" (code = *lesson-level responsiveness, modify the task*).

The goal of the focal lesson was "get some background knowledge on that, so that [students] can apply it." In designing her lesson, Ms. Chadwick looked for an "alternative" instead of simply giving a lecture. She noticed that students did not engage in the work as much as she wanted if they were asked to "go research this article and annotate that." She was "trying to come up with a way to essentially ask them to do [the same thing] but package it in a way that was more enticing" (code = *relational challenge, modifying task design*). Ms. Chadwick framed an activity as "helping the middle schoolers in Mr. Taylor's classroom." Mr. Taylor was Ms. Chadwick's teacher friend who was teaching seventh grade science in a nearby middle school. The main task given to students was to make a lesson plan, including "fun activities" about microbes and activities for seventh grade students in Mr. Taylor's class. Students as a small group were tasked with addressing the three following questions in their lesson plans: "1) What is a microbe? Are they good or bad? Add a fact or two about microbes here that you think kids will find interesting. 2) What are the four major kinds of infectious disease microbes? 3) How are infectious disease microbes transmitted (how do they move from one person to another, through mediums such as water, or sometimes from an animal to a person)? Explain and give some good examples." Ms. Chadwick decided to design her lesson in this way because she thought, "It would be fun." For Ms. Chadwick it was important that the students in this class "have fun" and "learn something," instead of "being miserable." She also thought that students would be more willing to do the work if it involved helping middle-school student, because then "they were doing it for a purpose more than just for the sake of learning something." In addition, Ms. Chadwick thought she could assess students' learning by looking at what her students came up with. She said, "If they're thinking about teaching it to a seventh grader, how are they going to explain that to a seventh grader or make it fun?" In addition, Ms. Chadwick decided to make the task "real" by choosing a real person, Mr. Taylor, so that students could ask him questions.

Ms. Chadwick encouraged students to pick their preferred lesson plan format, which resulted in a variety of artifacts, such as handwritten documents, PowerPoint slides, and Google Docs. Ms. Chadwick said, "Some of them prefer to do it handwritten, some of them prefer to do it typed, so I gave them options. They were welcome to do it on any format they wanted so." The task design allowed expression using multiple modalities, which helped her multilingual students,

including Tien and Victor, to access to translation tools and successfully create their own artifact (code= *linguistic challenge, modifying tasks*; see a photo of Tien's artifact in supplemental Appendix A).

The other task in the lesson was for students to design their own labs to test the transmission of diseases. Students had to generate potential variables that might affect the spread of the diseases, and then design a lab to test the effect of those variables. Ms. Chadwick noted that the students rarely had any lab experience in their previous Earth Science class. Running a lab with the student who had limited experiences of designing an experiment was not easy, and her first trial of having students design a lab did not go well. The following time, she decided to try it again with some adjustments. Ms. Chadwick thought that this experience of coming up with multiple variables, designing their own lab, testing their ideas, and reason through the processes, instead of just doing a "cookie cutter lab"—a normal practice of science teaching in this school–would help students become more "invested in the project" and be "valuable to [the students] outside of school too." She had no doubt that her Life science students could do this. She said, "There is no reason we can't [do this kind of lab]."

The teacher's in-the-moment pedagogical actions and students' OTL

In this section, we attend to in-the-moment interactions with special attention to one student, Carlos, throughout the lesson. Carlos was a 10th grade Mexican American boy from a low-income family. Early in the year, Ms. Chadwick learned that Carlos was involved in gang activity from Carlos's conversation with his friend Jose. Jose had transferred to the school from juvenile detention, and joined Ms. Chadwick's class later in the prior semester. Carlos and Jose frequently talked about gang interactions and their experiences while in Ms. Chadwick's class. Carlos often visited Ms. Chadwick's class and talked to her about his life outside of the school. For example, Carlos told Ms. Chadwick that one of his friends (Ms. Chadwick's student in her chemistry class) had been shot in his thigh. During the following semester, Jose was shot and killed. Ms. Chadwick said, "Carlos took it pretty hard. He knew them … He was trying to make choices to do better because, he knew that, I think he kept seeing that things are going on, and did not want that to be his future." Carlos's family supported him to get out of that circle. He decided to apply to a summer youth academy for Marines in a nearby city. This academy had a reputation of being a program for students that were likely to be dropouts or fall behind. At the moment, Carlos was waiting on acceptance into the program. For Ms. Chadwick, it had been a struggle as she tried to support Carlos, who frequently disengaged from academic tasks in her class. In her class, there were 21 other students who all had their own stories and needed her support, including Tien, Marcello, Brian, Victor, and all the others. Ms. Chadwick said, "We're supporting [Carlos] on his good choices. But it's still … [takes a deep breath]. He's making progress. It's definitely a different attitude from that group than the beginning of that year. But they're still a struggle. It's a little rough."

Ms. Chadwick's pedagogical actions and Carlos's participation in disciplinary practices. It was a day on which seniors took the California Science Test (CAST) in the morning. Due to this scheduled testing, the 10th grade students did not have to come to school until 10:30am, which made the class even more "squirrelly" in Ms. Chadwick's words. When the bell rang, several students, including Carlos, walked into the classroom. Ms. Chadwick greeted each of them individually saying, "How is your morning?" "Good morning, Carlos!," "[To the girl holding a birthday balloon] Is it your birthday, Maggie? Happy birthday!" The 60-minutes long lesson began with 'an index card activity' (i.e., warm-up). While Ms. Chadwick took attendance and the class settled in, students were asked to write down their answers to a question projected on the screen for five minutes. The question was "When an epidemiologist (somebody who studies epidemics) is trying to prevent or stop an outbreak, she focuses on one point of the triangle (Host, Agent, or

Environment). Based on what you learned so far, why do you think that strategy works? (3 sentences)"

As students found their seats, a few students came to the front to get papers or pens from Ms. Chadwick. Students chatted with each other. Ms. Chadwick moved to the table to answer the question of a girl sitting next to Carlos. While talking to the girl, Ms. Chadwick noticed from Carlos' tone and body language toward his friend at the next table that he was using inappropriate language in Spanish, even though she did not know exactly what he was saying (event #12, 2:55):

Carlos: No mames guey, cargala puto (translates to: Stop f***ing around bro, where's the charger b**ch)

Ms. Chadwick: [turn her head and make eye contact with Carlos] Hey, hey! [Carlos looked at Ms. Chadwick] Kind words, even in Spanish.

Carlos: I just said, best friend-

Ms. Chadwick: [with a firm and short voice] No. No.

"Be NiCe" was one of the signs on the classroom wall (spelled out using chemical elements' symbols from the periodic table) to communicate a norm of this classroom learning community. The majority of the learning activities were designed as collaborative work in this class. This norm of "be nice and respectful to each other" was crucial to facilitating students' productive interactions in this classroom setting. Carlos, who just entered into this classroom space, however, had not fully transitioned his ways of interacting with his friends to what was expected in this classroom space. Ms. Chadwick noticed and reminded him of the norms and rules of classroom interactions, reinforcing the value of treating people with respect in this space. It is notable that 'reminding the norms and rules of the behaviors to create a supportive learning community' was the most frequently observed pedagogical actions to address relational challenges in this lesson ($n = 52$ out of 123 events, 42.3%) as well as across the six lessons ($n = 152$ out of 638 events, 35.6%; see Table 1).

Carlos and his partner, Juan, pulled out their laptops and began to work on their lesson plan. They chose to use Google Doc, so they could write their answers to three questions together (see the questions in the previous section). When Ms. Chadwick visited Carlos's table, Carlos was casually chatting with his partner, Juan. They had not yet started working on their lesson plan. Ms. Chadwick seamlessly entered the conversation with Juan and Carlos by adopting their "plan of attack" metaphor:

Ms. Chadwick: What's our plan of attack here? [Ms. Chadwick was asking, "how are you planning to answer the three questions?"]

Juan: Alright, we're gonna hit 'em with the left hook, then slip, and then a right. [the boy is using boxing terms to jokingly answer Ms. Chadwick's question of how he is going to go about answering the three questions]

Ms. Chadwick: Okay, show me where the "left hook" is on here is [pointing out their Google Doc].

Juan: It's right here, look, all of this and then this is the "slip" right here, and then this is the "overhand right"

Ms. Chadwick: Okay, we gotta get working on the "overhand right" then [pointing out they haven't completed the third question]

Juan: Yeah we got that.

Ms. Chadwick: Okay.

In this exchange, Ms. Chadwick asked Juan and Carlos to show their answers to the three prompts of the task by prompting them to share "our plan of attack." The students jokingly answered Ms. Chadwick's request using boxing terms (i.e., "left hook," "slip," "right hook"). Ms. Chadwick responded to Juan and Carlos using their boxing terms, while highlighting the area

that they needed to work on more ("okay, we gotta get working on the 'overhand right' then"). It appeared that responding to Juan and Carlos using their vernacular language that not only made the situation playful but legitimized the two students' ways of talking and being in this space. Ms. Chadwick further pressed them to work on the academic task by pointing out what needed more work. Juan and Carlos got back to their "overhand right" of the task after Ms. Chadwick left their table.

When Ms. Chadwick returned to Carlos's table once again, about 17 minutes into the lesson, Carlos was arguing with Juan, about their response to question #3: "How are infectious disease microbes transmitted (how do they move from one person to another, through mediums such as water, or sometimes from an animal to a person)? Explain and give some good examples." Carlos thought fleas could be an example of an animal medium that transmitted diseases to human, but his partner Juan disagreed. Juan did not think humans could get fleas from a dog in the first place. As Carlos noticed Ms. Chadwick was approaching to his table, Carlos turned to Ms. Chadwick and asked her opinion:

Juan: You can't get fleas from a dog. A dog cannot give you fleas.

Carlos: [look at Ms. Chadwick] Can a dog give you fleas?

Ms. Chadwick: [It is] out of shot.

Juan: No, it can't!

Ms. Chadwick: Fleas don't generally like people because there are few places for fleas to live on us, but you *could*. It's just generally rare.

Carlos: Can that be an example of that?

Ms. Chadwick: [Ms. Chadwick read Carlos's written responses on the Google Doc]

Carlos: [annoyingly] What's up? [Carlos made a face at a student at the next table who wondered what was going on Carlos's table. The tones of voice and body gesture suggested Carlos' frustration about the fact that his idea was 'wrong']

Ms. Chadwick: [After completing her reading] Can you tell me why that's an example or what that's an example of. Are we going through bugs?

Carlos: Well, I went to, from drinking from the same bottle, to sharing food and eating from the same utensils, to then touching a dog that has been contaminated with fleas.

Ms. Chadwick: Okay. So, are we going with the insects or how is that a disease from the fleas? So fleas are not microbes, they're not a disease. They're a pain in the butt, but they are not a disease. So tell me how that's a disease?

Carlos: Never mind then, cause they're not a disease [Carlos tried to dismiss his idea]

Ms. Chadwick: But, if we are looking at bugs. If we are looking at bugs, is there any other bugs that cause diseases?

Carlos: Umm, [a few seconds to think] mosquitos?

Ms. Chadwick: There we go.

Carlos: So change it.

In this event, Carlos was actively engaging in the academic task in collaboration with his partner. He was trying to figure out whether fleas could be a good example of a medium of transmitting diseases from animals to humans. Notably, Ms. Chadwick persistently positioned Carlos as a capable science learner throughout these interactions. Ms. Chadwick shifted the discourse between Juan and Carlos from a dichotomist argument (right or wrong) to a contextual one. She drew Carlos's attention to relevant information ("Fleas don't generally like people because there are few places for fleas to live on us") without positioning Carlos as wrong ("you could. It's just generally rare") (codes=*intellectual challenge, drawing students' attention to key information or*

pattern). As Ms. Chadwick noted that Carlos, who was "used to failing at schools all the time," quickly tried to dismiss his own idea ("never mind!"), she encouraged him to continue his line of thought by asking a question about "other bugs that cause disease." In fact, I frequently observed that students in Ms. Chadwick's class tended to quickly dismiss their own ideas or quickly stop trying when they felt wrong or the task felt too hard. Ms. Chadwick attended to students' frustration or insecurity, and provided some form of emotionally encouragement or reassurance for students in those moments. The code of 'emotionally encouraging/reassuring the good progress to motivate a student' was the second most frequently observed pedagogical action to address students' relational challenge across the six lessons ($n = 143$ events, 33.5%; see Table 1). As illustrated by these interactions with Carlos, this pedagogical action appeared to help students maintain their epistemic agency. Carlos and Juan revised their lesson plan after these interactions with Ms. Chadwick. In the submitted document, they stated, "You can also get contaminated by a mosquito bite" (see Carlos and Juan's learning artifact in supplemental Appendix B).

Around the mid-point of the class (30:00), Carlos began to show 'off-task behaviors.' When Ms. Chadwick noticed him socializing with his friend, she walked to Carlos and talked to him quietly:

> Ms. Chadwick: How's summer plans going?
>
> Carlos: Just waiting for news [from the Marine academy].
>
> Ms. Chadwick: Do you have good feelings or bad feelings?
>
> Carlos: Good.
>
> Ms. Chadwick: Good! [Ms. Chadwick made an eye contact with a smile, and left the table. Carlos got back to his lesson plan.]

When asked about this interaction during the post observation interview, Ms. Chadwick shared the tensions that she felt in responding to Carlos's behaviors:

> He [Carlos] actually, he is a bright kid. He wasn't working very hard. But I don't think, especially based on how I had talked to him, a lot of time yelling at him or nagging him, it wasn't getting him anywhere. So what could I do that would be supportive to help us to move forward? … At the end of the day, what this completing task is getting at to [Carlos] … it is more important that kids have a place that can be safe, a place that they can talk to an adult … it is more important for him to have a place that he wanted to come in to, than the place for me to yell at him to get the work done.

Ms. Chadwick's pedagogical action in the above event, in which she asked about his summer plans, was coded as 'talking about students' life outside the school to affirm students' choices.' Across the six lessons, we observed this pedagogical action in 16 events (approximately 3 events per lesson; see Table 1), suggesting ongoing attention to students' life outside of the classroom. While working with students like Carlos, Ms. Chadwick chose to prioritize supporting her students to relate themselves to other people and the classroom space over the completion of a specific academic task in certain moment. Through this short moment of interactions, Ms. Chadwick chose to show Carlos that there was a person in this class who cared about him and his well-being. It appeared that this relational pedagogical action, which validated his presence and struggles and life choices, increased his opportunity to learn in this class as evidenced by Carlos refocusing on his task after his interactions with Ms. Chadwick and the produced artifact.

The last ten minutes of class time were used to plan an investigation of the transmission of diseases. To create a connection to the theme of the unit, Ms. Chadwick asked, "How could we prevent ourselves from getting sick?" Students, including Carlos, expressed various ideas, such as "[wash] your hands with hand sanitizer," "don't touch each other," "don't go outside," "be cleaner," and "exercise more." Students were asked to "decide what [their] group would like to test." After five minutes of small group discussion, the class brainstormed an idea for investigation. Students were asked, "What can we measure to see if hand sanitizers are working?," "What's

the obstacle we need to plan for? What's the problem that we can have worrying in this lab?," "How can we measure how effective something is?" and "So if we are measuring transmitting of diseases, how are we going to get data?" Students left the room anticipating that, on the following day, they would test how effective hand sanitizers are in preventing the spread of germs.

Epilogue and summary

Later in the year, we heard that Carlos was accepted to the summer Marine academy. Ms. Chadwick received a hand-written letter from Carlos over the summer that began as follows: "Everything in here is all right. Some days are hard, some days are good … the first 2 weeks of the program were the hardest but I didn't quit." Carlos shared his good memory in Ms. Chadwick's class: "I was probably your best student in your class, haha … some good memories in your class. Your class was the best." After completing the academy, Carlos returned to school. Ms. Chadwick said,

> He was in Mrs. Smith's class in second period. He is not an 'ideal' student. The last time when I checked, he is doing better. He is on track to be graduate. He didn't have to go to the continuation school. He is doing well, so I am excited about it. He is ALIVE, so I am excited about it.

The pattern of Ms. Chadwick's attention and pedagogical actions observed in this lesson (123 events) were largely consistent with the broader patterns observed across six lessons (638 events, see Table 1). Ms. Chadwick continuously attended and addressed students' intellectual, relational, and linguistic challenges. The most frequently observed pedagogical action to address students' *intellectual* challenge was *drawing students" attention to key information or pattern*, followed by *reminding the goals and directions for the task*. The most frequently observed actions to address relational challenge was *reminding norms and rules of behaviors to create supportive learning environment*, followed by *emotionally encouraging/reassuring the good progress to motivate students*. The three forms of pedagogical actions taken by Ms. Chadwick to address *linguistic* challenges were: *adjusting task to students' capabilities and needs on the linguistic level, paring the multilingual student with a friend who can help, connecting to everyday language/experiences to help students to generate meanings of the academic language*. Across the six observed lessons, Ms. Chadwick persistently and intentionally created opportunities in which students could have fun, ask questions, and think about ideas while working against the dominant negative discourse, culture, and ideology of what it means to teach and learn sciences.

Discussion

Teachers' responsiveness for equity in practice

Prior studies have characterized teachers' responsiveness or responsive teaching by primarily focusing on discursive patterns observed during instruction (e.g., Colley & Windschitl, 2016; Hutchison & Hammer, 2010; Thompson et al., 2016). In this study, I theorize that teachers' responsiveness that promotes equity expands marginalized students' opportunity to learn (OTL) in disciplinary classrooms. In this conception, a key characteristic of responsiveness for equity is taking actions that are consequential. By consequential, I mean that the teacher's actions change the characteristics of the activity system in a way that improves conditions for students' disciplinary engagement in the moment. The analyses point to three features that constitute teachers' responsiveness for equity.

First, taking pedagogical actions that expand students' OTL requires teacher attention to marginalized students' identities, historical experiences, relationships, and struggles, in addition to the ideas or thinking strictly relevant to disciplinary learning goals (see Agarwal & Sengupta-Irving, 2019). In this study, students' struggles often manifested as a form of emotion, feelings, or

behaviors, suggesting various important relational challenges. The students, who had been placed in a "lower track" science class, tended to quickly dismiss or give up on their own ideas, indicating difficulty seeing themselves as capable science learners. Recall Carlos, who struggled to get out of the gang circle and make a better choice for his life. Carlos demonstrated what is commonly referred to as 'misbehavior' or 'off-task behavior' several times throughout observed instruction, indicating the challenges he faced in fully bringing himself into the classroom space. Ms. Chadwick's relationship with Carlos gave her access to his stories, identities, and life circumstances outside of school. Ms. Chadwick's attention to his struggles in turn led her to prioritize the goal of creating a "safe" space in her classroom for Carlos in the moment. It is important to note that Ms. Chadwick constantly validated and legitimized her students' ways of thinking, talking, and being in the classroom space by taking up their vernacular to support engagement in disciplinary practices, and by persistently positioning students as capable science learners. The majority of students in Ms. Chadwick's class, including Carlos, struggled to navigate and participate in the classroom learning communities. Ms. Chadwick repeatedly reminded her students of the norms and rules of behavior (152 events; see Table 1), emotionally encouraging or reassuring them of their progress to motivate students (143 events), showing her appreciation to validate who the student is and what she does (61 events), and connecting a struggling student with a friend to help (12 events). A key aspect of teachers' responsiveness that promotes marginalized students' disciplinary engagement in classrooms included addressing relational challenges—how students might struggle to navigate and participate in the classroom learning community—by helping students relate themselves to the discipline (i.e., academic task), people (i.e., peers and the teacher), and classroom space (i.e., place).

Second, the analyses show that taking actions that expand students' OTL involved the teacher deliberately working against the prevalent culture, ideology, and norms in order to persistently position students as capable sense-makers. In a study about a mathematics teacher's noticing, Louie (2018) demonstrates the political nature of teacher noticing. This study further shows that taking actions that expand marginalized students' OTL is a political act of actively resisting prevalent discourse, expectations, and norms. Recall Ms. Chadwick was willing to give up a good observation score in the area of classroom management on evaluations of her teaching. She designed lessons where students had fun together, engaged in deep thinking and meaningful disciplinary practices while fighting against the negativity and low-expectations toward students in the Life Science class. Recall the task of planning a lesson for Mr. Taylor's seventh grade students. Learning about microbes could involve passively receiving knowledge from authoritative sources, such as either through lecture or reading scientific articles. In those activities, students would be positioned as the receivers of knowledge by the activity's design. Instead, the teacher designed experiences in which students were positioned as experts (i.e., in knowing what seventh graders would find interesting about microbes) who were qualified to help both a middle school teacher *and* his students in producing lesson plans and activities. By doing so, the students, who were considered unlikely to succeed in upper-level science classes by their middle school teachers, adopted a position from which they could help a teacher. It appeared that problematizing the prevalent norm of school sciences was particularly important for those students who entered the classroom with a history of "failure" or "being wrong" in school science classes. Reestablishing the rules and norms of high school science classrooms appeared to require repeated, timely, and explicit communication with students. It is worth noting that the teacher navigated diverse ideas without positioning students' ideas not aligned with canonical science ideas as wrong or incorrect. Ms. Chadwick treated her students' ideas with respect, a crucial pedagogical move to promote equity (see Rosebery et al., 2016). In this study, the teacher complicated students' ideas by drawing their attention to relevant information (198 events, see Table 1), and connecting or comparing these different ideas among the entire classroom (71 events).

Finally, the analysis suggests that expanding students' OTL necessitates involves the teacher's pedagogical actions at every stage, from planning to enactment of the lesson, beyond just in-the-moment action. The findings of this study show that the conditions for student participation at any given moment are not only co-constructed by the teacher and her students through in-the-moment interactions, but also cumulatively shaped by a teacher's layered pedagogical actions at the unit- and lesson-level. Recall Ms. Chadwick's virus and bacteria lesson with her 10th-grade students. The majority of her students were Mexican American and excited about an Olympic event occurring in South America. Framing the focus of the unit by leveraging students' interest and curiosity (i.e., addressing relational challenge, unit-level responsiveness) contributed to marginalized students' improved OTL by facilitating personal connections to academic tasks. The students in this class had been placed in the "lower-track" science class after two "failures," yet were able to actively and meaningfully participate in academic tasks. Ms. Chadwick designed an intellectually challenging task (i.e., identifying multiple variables, designing a lab to test their own ideas) while positioning students as capable sense-makers. Furthermore, the teacher took various pedagogical actions when designing the lesson to address students' difficulties in engaging in disciplinary practices. For example, the teacher changed the topic of her lesson to supply an essential reasoning resource (i.e., the difference between bacteria and viruses) for figuring out how to prevent the spread of Zika virus during the Olympics. The teacher humanized learning experiences by framing the task for a real person in order to help the seventh graders. The important role of a teacher's pedagogical actions during the planning stage, as a means of improving students' OTL, has been suggested by other studies (see Kang, Windschitl, Stroupe, & Thompson, 2016; Stein & Lane, 1996). In the analysis of 57 science lessons, for example, Kang and colleagues found that teachers who successfully engaged students in meaningful disciplinary practices during instruction tended to use "adapted" curriculum, instead of using department curricular material as-is. I speculate that the act of adapting curricula at the planning stage might be an indicator of the teacher's responsiveness in creating better conditions for particular groups of learners.

Complexity of studying teachers' responsiveness for equity: methodological dilemmas

The conception of teachers' responsiveness for equity led the researcher to engage in two analytical activities to explicate such pedagogical actions. One analytic activity was describing observable teaching behaviors and the other was interpreting its meaning focusing on students' OTL. Grounded in sociocultural and situative perspectives, I posited that the meanings were co-constructed among the actors in their contexts. This conception poses several methodological dilemmas in recognizing teachers' responsiveness for equity.

The first dilemma is whether it is possible to recognize teachers' responsiveness that promotes equity only through brief observation with limited information about the context and learners. Recall Ms. Chadwick's short interactions with Carlos about his summer plan in response to his 'off-task' behaviors. The researcher found new meanings contained within these short interactions again and again as the researcher learned more about Carlos, his stories, his relationships with the teacher and classmates, and eventually, his life pathways. The researcher could access such information only because of the deep, long-term relationship maintained with the teacher even after data collection was completed. This study shows that a teacher's capacity to take actions that expand students' OTL depends largely on her relationships with students and understanding of each student's context. Similarly, it appears that a researcher's capacity to recognize a teacher's responsiveness that promotes equity depends largely on the researcher's understanding about and relationships with the participants in these contexts. Cultivating such relationships with participants takes a substantial amount of time and effort. Without such relationships, however, it might be difficult to recognize such seemingly trivial teaching behaviors that are in fact consequential.

The other dilemma emerging from the analysis is the inherent uncertainty of the presented meanings of pedagogical actions. Grounded in sociocultural and situative perspectives, I conceptualize that students' OTL is dynamically and relationally co-constructed among the teacher and students. A teacher's pedagogical actions that change major components of the activity system, such as features of task design, roles and relationship among students, and tool use, have the potential to increase affordances of the classroom setting for a particular student's disciplinary engagement. By collaborating with Ms. Chadwick, the researcher could co-construct the meanings of particular pedagogical actions in relation to students' OTL with the input from the teacher; however, the presented meaning was still incomplete in a sense that it did not reflect students' perspectives. In this study, the researcher used students' enhanced participation in disciplinary activities before and after their interactions with a teacher as an "indicator" of desirable changes within the activity system, mediated by the teacher's actions. One possible direction for the future research is collaboration with students alongside teachers to co-construct the meanings of observed teaching behaviors in relation to students' OTL.

Finally, and in relation to the above two dilemmas, this study raises a question about the effort to identify, teach, or learn the singular teaching practice that *is* equitable or culturally responsive. With a deep concern about the persistent inequity and injustices experienced by students from non-dominant communities, there have been numerous attempts to identify equitable or culturally relevant teaching practices in teacher education community. In this study, I presented the various pedagogical actions observed in the Ms. Chadwick's instruction (see Table 1), but I do not think that they are *the* definitive set of equitable practices that promote equity for all marginalized students in every context. As shown in the case of Carlos, the meanings of a pedagogical action are deeply rooted in their context and depend heavily on learners. Our aspiration to promote equity often leads us attempt to identify singularly equitable or culturally relevant teaching practices. By searching for or teaching observable teaching practices that *are* equitable, however, we may run the risk of continuing to lose those students who have been historically and are currently marginalized at schools.

Conclusion and implications

In this study, I theorized that practices of teachers' responsiveness that promote equity expand marginalized students' opportunity to learn (OTL). The analysis showed that a responsive teacher who expanded students' OTL attended to students' identities, historical relationships, and struggles, in addition to students' ideas, and addressed students' relational challenges in participating in disciplinary practices at the stages of *both* planning and instruction while working against settled hierarchies, cultures, and ideologies reflected in dominant discourses. In addition, this study shed light on the methodological complexity and dilemmas inherent in studying teaching with a focus on responsiveness for equity.

There are two implications emerging from this study for practitioners and researchers interested in studying and improving teaching. First, this study calls for more explicit attention to the methodology and articulation of the underlying theoretical perspectives of researchers who study the work of teaching. Researchers' methodological choices, such as selection of data sources, unit of analysis, and analytical approaches, all lead to the generation of different insights into teaching, even when different researchers have the same goal, such as understanding teachers' responsiveness or responsive teaching. Careful attention to methodology—including underlying theoretical perspectives on learning, the role of the teacher, and broader context—will further advance the knowledge base on teaching and teacher learning.

Second, a future study that explores teachers' responsiveness in different contexts will further deepen our understanding of teachers' responsiveness that promotes equity. It is important to note that, in this study, data were generated within an early-career secondary science teacher's

classroom during her 1st and 2nd years of teaching. I speculate that more sophisticated pedagogical moves can be observed in the classrooms of more experienced teachers. I also speculate that teachers' responsiveness might play out differently in the elementary classroom setting, where a teacher works with young children in a single, contained room all day while teaching multiple disciplines. In addition, I conjecture that there might be notable similarities and differences in teachers' responsiveness that promotes equity across the disciplines. For example, the ways in which teachers attend to and address the epistemic injustice experienced by marginalized students might play out differently in mathematics versus science classrooms. I invite researchers to explore this important issue in various contexts, so that we can collectively deepen our understanding about the complex work of teaching.

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