Supporting Novice Teachers' Learning to Enact a Social Justice Framework of Science Teaching

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Abstract: We report on eight novice science teachers' efforts to enact a social justice framework of science teaching developed locally by university teacher education faculty. Enacting rigorous and equitable science teaching within urban schools serving low income families of color can be difficult for novice teachers. Our perspective on social justice science teaching relies on centering students' lives, histories, and experiences where teachers use a subset of instructional practices that support students' learning and participation in rigorous science instruction and create equitable access to science content for all students. We analyzed classroom observation ratings and video recordings of classroom teaching in order to understand novice teachers' development as social justice science educators. We found evidence that teachers improved over time in their efforts to use specific instructional strategies to enact social justice science teaching. In addition, there remain a few learning challenges, especially around centering students' lived experiences, histories, and assets.

Introduction

New science education standards demand that science teachers ensure equitable access to rigorous science instruction for students from historically underserved communities (Next Generation Science Standards, NGSS Lead States, 2013). Yet, analysis of the goals within the standards reveals distinct neoliberal values (i.e., promoting post-secondary science studies and/or pursuing scientific careers) (Hoeg & Bencze, 2017). While these pursuits are important, adequately addressing historical injustices and the silencing of non-dominant ways of knowing requires broadening the goals of the NGSS to include ideas such as developing students' capacity to participate in critical discourse around public science issues (Feinstein, 2011; Morales-Doyle, 2017). Social justice teacher education programs emphasize developing novice teachers' understanding of the social, political, and academic features of teaching within schools that predominantly serve students from working class communities of color (Cochran-Smith, Shakman, Jong, Terrell, Barnatt, & McQuillan, 2009). These programs support novice teachers as they develop social justice dispositions and goals through deep, sustained community and experiential learning opportunities (Baily, Stribling, & McGowan, 2014), through strategic student teaching placements with social justice oriented guiding teachers (Lane, Lacefield-Parachini, & Isken, 2003), and engaging instructional reflection around teachers' educational and personal experiences relative to their students' experiences (Howard & Rodriguez-Scheel, 2016). Yet, from a learning sciences perspective, the trajectories of learning along with the tools and resources that support teacher development, especially novice science teachers, are understudied.

As teacher educators, our work centers on social justice frameworks that serve as the foundation for preparing novice teachers and informs our analysis of their development. Bartolomé (1994) calls teachers to debunk notions of deficit thinking around the academic achievement of students who have been historically marginalized by adopting a humanizing pedagogy. Humanizing pedagogy involves respecting students through an asset-based approach such as culturally responsive education (Bartolomé, 1994). Yosso (2005) conceptualizes asset-based approaches to teaching as educators noticing the cultural wealth marginalized groups bring to the classroom from their families and communities and then drawing on these resources to inform their teaching. In our program, novice teachers dive deeply into what it means to be a social justice educator by reflecting on their multiple identities in relation to privilege and power. By understanding their positionality, teachers form a deeper understanding around why practices that value student voice are necessary for enacting humanizing pedagogy (Takacs, 2003). In doing so, teachers get to know students, their interests, lives, and histories, and learn how to provide the necessary resources and experiences that help students understand and interact with the content in meaningful ways (González, Moll, & Amanti, 2013). Our goal is for teachers to learn that in order to meet students' needs, critical theories and pedagogies must shape the way they approach science teaching.

From there, our perspective on rigorous and equitable science teaching begins with classroom teaching that promotes productive disciplinary engagement (Engle & Conant, 2002) where there is an emphasis on creating opportunities for student participation, voice, and agency (Lee, Quinn, & Valdes, 2013). Teachers must support students to take on intellectual responsibility for their own learning, as articulated in the conceptual framework underlying the NGSS (NRC, 2012). This includes students engaging in cognitively demanding performance-based tasks with direct connections to students' lives where students develop a deep understanding of concepts and skills through teachers' navigation and support of tasks, including appropriate checks for understanding. We view this type of science teaching as fundamentally dialogic (Kelly, 2014) and thus places two primary demands on teachers' practice. First, classroom norms and routines must be developed to ensure equitable participation among students (Franke, Kazemi, & Battey, 2007). Explicit modeling and negotiation of social norms that recognize power and culture in the classroom critically develop a safe and positive learning environment (Knight, 2001). The second demand follows from this, that teachers must manage classroom discourse, where students hold each other accountable to disciplinary standards of knowledge production (Elgin, 2013). In this paper, we examine multiple data sources to describe novice teacher learning around a social justice framework for science teaching.

Methods and study context

Using the above-mentioned social justice and science teaching frameworks, we developed and pilot field tested for reliability a classroom observation rubric (I-COR) that positions social justice values as the foundation for rigorous science teaching and operationalizes these practices for novice teachers (see Nava, Park, Dockterman, Kawasaki, Schweig, Quartz, & Martinez, 2019 for the pilot generalizability study results and the pilot study version of the I-COR). The I-COR dimensions served as the foundation for our science coursework and fieldwork and the primary formative assessment tool used to provide feedback to novice science teachers in our program. The I-COR contains four core dimensions of teaching quality, divided into 11 sub-dimensions (Table 1).

Table 1: I-COR core dimensions, sub-dimensions, and example instructional strategies

Dimension	Sub-dimension	Example instructional strategies
Scientific rigor	1a. Engaging students in rigorous task	Project and problem-based learning, performance tasks, NGSS science practices
	1b. Checking for understanding and feedback	Exit slips, thumbs up/down, agree/disagree community circles, think-pair-share
Scientific discourse	2a. Teacher discourse and questioning	Essential questions, make predictions, make conjectures, use evidence and rationale
	2b. Teacher facilitation, participation structures	Small, flexible, leveled groups, group roles, think pair share, sage & scribe, whip around
	2c. Student discourse, rigor	Using talk moves (e.g., say more, repeat/re-voice, own words, agree/disagree)
Equitable access to content	3a. Supporting development of academic language	Group projects, sentence starters/frames, choral reading, graphic organizers, quick write, say-mean-matter, KWL
	3b. Making content relevant for learners	Accessing prior knowledge, referencing lived experiences, real life application, projects
	3c. Differentiation, content and process	Multi-tiered tasks, application tasks, stations, integration of the visual and performing arts
Classroom ecology	4a. Classroom routines	Opening and closing routines, planned transitions, interaction routines
	4b. Community of learners	Community circle, social norms, contracts discussions, reflective conversations
	4c. Democratic classroom	Opportunities for multiple student voices to be heard, choice, voting, student feedback

For this study, we ask what are the successes and challenges of novice science teachers in enacting a social justice framework of science teaching? To answer this question, we analyzed observation ratings collected throughout the academic year for eight novice science teachers, looking at average ratings and standard deviations to identify dimensions of strength, weakness and growth for the cohort of teachers. In addition, we qualitatively analyzed teachers' self-recorded videos of whole class discussions collected at the end of the winter quarter in their science methods class to better understand the types of instructional strategies they used during these discussions and how they align with the dimensions of the I-COR. To analyze the videos, we used interaction analysis (Jordan & Henderson, 1995) to understand the consequence of novice teachers' teaching (e.g., questioning, facilitation, differentiation) on student participation and engagement in the whole class discussions. We assert that whole class discussions are one particular participation structure where all the I-COR dimensions might manifest during instruction. Each teacher recorded 1−2 videos with whole class discussions, totaling 15 recorded whole class discussions across the cohort. Video recorded whole class discussions range from 4-11 minutes, with an average of 7 minutes.

Findings

We calculated means and standard deviations across all observation ratings during each academic quarter (see Table 2). All the observations were conducted by the same faculty advisor and all teachers in the cohort were observed 2−3 times per quarter. The I-COR ratings are on a 4-point Likert scale (i.e., 1-Absent, 2-Emerging/Applying, 3-Integrating, 4-Innovating).

Table 2: Average observation ratings for novice science teachers (n=8) by academic quarter

	Academic rigor	Academic discourse	Equitable access to content	Classroom ecology
Fall (n=20)	2.78 *(.58)*	2.88 *(.67)*	2.72 *(.67)*	3.03 *(.69)*
Winter (n=21)	2.83 *(.58)*	2.79 *(.57)*	2.78 *(.61)*	3.05 *(.55)*
Spring (n=16)	3.13 *(.42)*	3.13 *(.61)*	3.00 *(.58)*	3.46 *(.58)*

Note: Total number of observations across each quarter are listed in first column. Standard deviations are in parenthesis next to average ratings.

There is a noticeable upward trend in means across all dimensions from the fall to the spring quarter, suggesting that as a group, teachers were more frequently using the strategies from the I-COR. Overall, standard deviations became smaller over time across all the dimensions, suggesting that the range of ratings were wider during the fall and became more centered on the higher scores by the spring quarter. These are both positive indicators that teachers within this cohort became better at enacting instructional strategies that pursued rigorous and equitable science teaching. We view these ratings as qualitative data that suggests observable differences in teaching from the beginning of the year to the end of the year. To explore this trend further, we looked at 12 videos of whole class discussions in order to identify which of the strategies were most commonly used and what were some of the challenges that teachers faced around the I-COR dimensions. Each of the examples we share depict exemplars of how teachers enacted the dimensions and subdimensions within the I-COR.

Scientific rigor

Six of the eight teachers designed their whole class discussions around student generated data (e.g., analyzing phenotypic ratios for students' genetic traits, empirical data collected from testing school water samples for contaminants) and the other two teachers focused their discussion from online simulations (e.g., earthquake modeling and epicenter predicting). Figure 1 is a screen capture of one such example, where the teacher created a class chart with five different genetically passed on traits (i.e., tongue rolling, attached/detached earlobes, hair color, eye color, and widows peak). In the screen capture, each trait is listed on the large poster paper at the front of the room and contains two bar graphs for each trait, one for the recessive trait and the other for the dominant trait. Students were asked to predict the genotypes for their parents based on the classroom data for each of the traits. Similar charts of aggregated student data were used in the other videos. We view these types of whole class discussions as *engaging students in rigorous tasks* (subdimension 1) because they are grounded in students' lives and interests and promote student participation in the science and engineering practices of the NGSS.

In terms of the second subdimension for scientific rigor, we share one example of a middle school physical science teacher using a specific strategy for *checking for student understanding* during an activity where students were using a computer simulation for how early humans survived as a community.

> I need a thumbs up, thumbs to the side, or thumbs down; thumbs up if you remember how to play [the computer simulation], thumbs down if you have no idea. (Students all raise a thumb with either up or down, none to the side). Ok, so thumbs down, I'm going to come and check on you. Thumbs up, go ahead and just jump back into it.

Although, this particular example was not specifically addressing student understanding of content, it was a strategy that all students responded to appropriately indicating that the thumb-signaling strategy was a common practice within this classroom. Finding ways to support novice teachers to use both informal and formal checks for understanding around the specific science ideas and practices under study is an area that needs further attention.

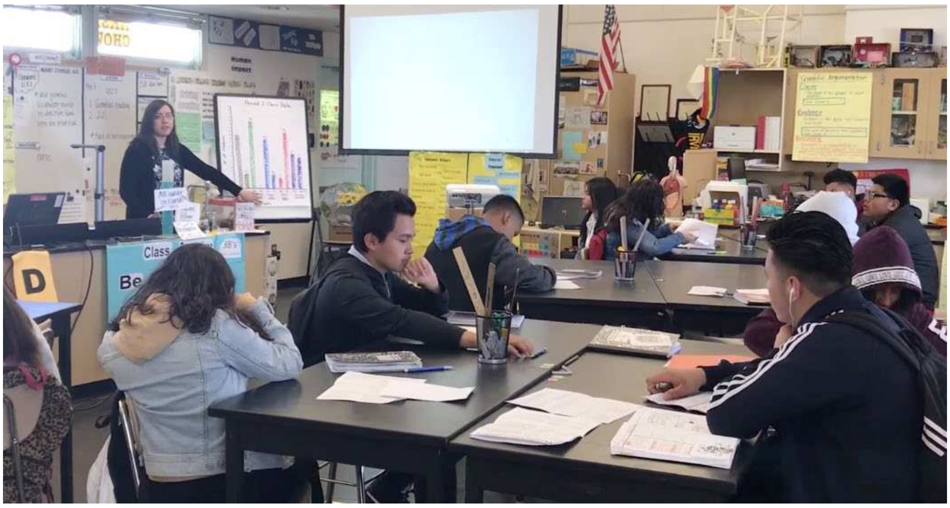

Figure 1. Screen capture of whole class discussion around genetically passed on traits.

Scientific discourse

Supporting teachers to promote classroom discourse is a major emphasis in our teacher education program because it engages students in discussions that mirror the types of knowledge production conversations and consensus building among practicing scientists (Manz, 2014). In addition, student discourse is a way to empower students by giving them voice and placing value in their ideas, experiences, and histories that they share with the class (Rosebery, Warren, & Conant, 1992). Among the teachers in this sample, a common *teacher questioning* technique was asking students to provide evidence to support their claims. One example is from the same conversation in Figure 1 about genetically passed on traits.

T: Why would our parents not be heterozygous for eye color? How do we know?

S1: They would be because it said that 25% would have blue eyes and there's nobody with blue eyes here.

T: Who else might agree with that? Anyone disagree? Can we say that our parents are heterozygous for tongue rolling?

S (many): Yes!

T: Why do we say that? What in our data tells us that?

S2 Because we expected 75% and we have 73%

T: So, you are saying that 73% can roll their tongue

S1 and S2 responded to this ask for evidence appropriately citing the similarity between the actual percentages from their class experiment as compared to the estimated percentages from Gregor Mendel's pea plant experiment.

For *teacher facilitation and participation structures,* the common discursive pattern was for teachers to elicit a student's idea and then use a strategy known as revoicing (O'Connor & Michaels, 1993) in order to reiterate and clarify a particular student's thinking for the rest of the class. Teachers also used different participation structures such as small groups and pair-share during the discussions as a scaffold for student participation. One example was from a class discussion where middle school students were trying to resolve a disagreement. The students were looking at class data from an online simulation of a chemical reaction between baking soda and vinegar and were arguing about whether allowing the chemical reaction to run longer might account for the different results each group obtained from the simulation.

S1: If you let a chemical reaction run for a long time.

T: You're talking about the start time right, (student nods). So how many of you think the start time would affect your results. If you started at one point and let it run all the way, would it change what you get?

S (many): No

T: Why do you think it might not change?

S2 Because it depends on how many times you click for baking soda, unless you change it, then it wouldn't change. Like you add more baking soda, for the next time you stop, then it will change

T: So, you are telling me that the total number of atoms that's involved in the chemical reaction that's not determined by time, that's determined by how much baking soda you've added, right? And so, the only time the total number of atoms would be different is if you added more or less baking soda, and so the time doesn't matter.

This teacher takes a rather sprawling student utterance and re-voices it in clear scientific terms (i.e., student's explanation that time does not matter in the amount of product you make, only the amount of reactant matters).

The most common challenge that we saw in the whole class discussions was the recursive teacher-student discourse pattern. There was little to no student-student discourse in any of the whole class discussions. We view student-student discourse as a benchmark feature of *rigorous student discourse*. Although teachers used talk moves designed to promote student-student talk (Michaels & O'Conner, 2012), such as asking for whether students agreed or disagreed with others or asking students to add-on to another student's idea, in practice these moves were used when the teacher was looking for a particular response (i.e., correct answer). Most times, once the correct answer was given, the teacher moved on and the discourse typically ceased. Finding ways to support teachers to design instruction around uncertain ideas where multiple answers are plausible is needed to promote more student-student discourse.

Equitable access to content

One common strategy for supporting the *development of academic language* was the use of sentence frames to scaffold student participation in the whole class discussion. In one middle school teacher's class discussion around energy and mass conservation, he offered a sentence frame to help students write down their ideas.

T: The first question asks to describe the atomic composition. Those are kind of fancy words, it really just means what is this molecule made up of. Can someone remind me the molecular formula of oxygen gas?

S1: O2

T: So how would you describe this molecule? A sentence frame that you can use is (teacher writing on the board) 'Oxygen gas is made of <blank> atoms of <blank>'. If you are not sure, you can flip over to the table on the backside to figure out how many atoms is it made up of and what are the elements that make up that molecule.

The teacher used two strategies for developing academic language. First, he puts the science question stem into everyday language (i.e., those are fancy words…). Then he provided the sentence frame so that students could respond to the prompt in an appropriate manner.

In terms of *making content relevant*, there were a few instances where teachers used relevant examples of everyday life to connect to the science that students were learning (e.g., studying genetic traits, looking at earthquake epicenters, studying local water contamination). Yet, it was not clear that teachers asked students to use science concepts to explain real-life phenomenon as stated in the NGSS. Whole class discussions can be productive opportunities for students to share their ideas, critique others' ideas, and make sense of science ideas relative to an anchor phenomenon (Sandoval, Kwako, Modrek, & Kawasaki, 2019), yet in this sample of teachers and whole class discussions, there was no evidence of such discussions. Lastly, we saw no examples of differentiating instruction in the whole class discussions. This is not to say that there was no differentiation happening in other aspects of instruction, but whole class discussions are a participation structure that requires additional scaffolds to ensure equitable participation. This is another challenge that needs additional attention especially for novice teachers.

Classroom ecology

The first feature of building a positive classroom ecology is the development and use of *classroom routines*. Given that there was often small group talk prior to the whole class discussion, teachers often needed to get students attention for the discussion. Two teachers used a countdown method (e.g., "Alright, let's come back together in three, two, one. Let's all look this way") whereas two other teachers used a hand-raising technique (i.e., teacher raises his/her hand and as students notice the teacher the end their conversation and raise their hands). In all these examples, students responded appropriately by finishing their last sentence, quieting their voices, and turning their attention to the teacher indicating that this was a consistently used classroom routine.

In terms of *building a community of learners*, there were two instances where teachers reinforced social norms for participating in a whole class discussion. In one instance, a middle school life science teacher reminded her students to direct their attention, posture, and eye gaze towards the student sharing. “Remember when somebody is speaking, everyone is paying attention and quiet and your attention is directed towards the student”. (Teacher gestures with both arms straight and pointed directly in front of her to show that students should be facing the student talking). Another teacher reinforced the idea that when a student shares, they should be appreciated by the entire class for their contributions. “Really good job, can everyone give a round of applause. (Teacher begins to clap, but only a few students start clapping). Again, remember that everyone applauds for everyone”.

In terms of developing a *democratic classroom*, two teachers used equity sticks (i.e., cup filled with popsicle sticks with each one having a students’ name written on it) and two other teachers asked for additional participants who had not yet shared during the discussion as a way to get multiple voices involved in the discussion. For example, one middle school physical science teacher used a discussion where he asked other groups to agree or disagree with the findings one group shared from their water contaminant experiment technique (i.e., see talk moves, Michaels & O’Conner, 2012). In this discussion, one group shares their claim that the contaminant is excess salt and he asks another group to share their conflicting finding.

T: Can one of the Epsom salt groups, someone tell me, why did you come to that conclusion?

S1: Because our data says that Epsom salt has conductivity, and contaminated water has conductivity also

T: Ok, so S1 was saying that both of them conducted and both had similar boiling points. So, we are trying to find which one is the same, so you look for things that look the same. So, did any of the other groups do the same things. How about your group, you had sugar and saw that it was similar and was conductive too?

In this example, the teacher attempts to juxtapose conflicting claims, explicitly calling out the disagreement between two groups. This not only encourages participation across multiple students in the class, but positions their participation as trying to resolve a scientific disagreement and develop some type of consensus.

Discussion and implications

Our study sought to better understand what science teaching from a social justice perspective looks like in the classroom. To do this, we used a framework for social justice science teaching to examine observation ratings from novice science teachers’ teacher preparation fieldwork experience to assess their development over time and we used self-recorded videos of whole class discussions from their winter quarter science methods class to better understand the specific strategies they used to enact social justice science teaching in their classrooms. As a group, the dimension positive classroom ecology, had the highest observation ratings by the spring quarter suggesting that novice teachers as a group were the most developed in terms of using classroom routines and reinforcing social norms, features of classroom teaching that are imperative for promoting education equity in the classroom (Franke et al., 2007). In the videos of whole class discussions, this was evidenced by: 1) all the teachers using some type of classroom routine to get students attention and most importantly, the students responded to these routines appropriately, 2) a few teachers reinforcing social norms for contributing and participating in whole class discussions, and 3) all the teachers using some strategy to promote multiple student voices within the discussion. Our past experience and research have suggested that this dimension is the one where teachers in our program develop most quickly and consistently (Kawasaki, Park, & Nava, 2018; Nava et al., 2019), despite other research that suggests that promoting positive classroom norms and routines are especially difficult for novice teachers (Ghousseini, 2015; Lampert et al., 2013). Our video analysis identified the concrete strategies that teachers used to promote a positive classroom ecology suggesting that opportunities to practice and reflect on these during their teacher preparation program contributed to their uptake of these practices within their fieldwork placements.

For the other dimensions, teachers were largely split between integrating and emerging in their proficiency (i.e., scores between a rating of 2 and 3) with using the strategies in their classroom. In the videos, teachers used strategies from some of the subdimensions such as designing rigorous tasks, asking effective questions to promote discourse, and developing students’ academic language. Yet, it was clear that teachers also needed further support in a few of the subdimensions, namely, making content relevant, differentiating instruction, promoting student-to-student discourse, and checking for student understanding. Supporting teachers in learning to elicit, notice, and respond to student thinking is a difficult task for novice teachers (Kang & Anderson, 2015).

This suggests that our teacher education program might consider additional structures within coursework and fieldwork, such as rehearsals and field-based methods courses (Kazemi & Waege, 2015; Lampert et al., 2013) or video analysis (van Es, Cashen, Barnhard, & Auger, 2017) to support teacher development in these needed areas.

We draw two conclusions from these findings with implications for teacher educators and preparation programs geared towards developing social justice science educators. First is that the I-COR served as a tool that made our vision for social justice science teaching concrete and supported teachers to enact strategies and practices that aligned with this vision. We argue that the I-COR creates a common language and shared vision between university faculty and novice teachers that enables them to have conversations around areas of strength and growth to support novice teacher learning. Second, we acknowledge that developing the skills and capacity to enact a subset of instructional strategies is not enough to truly pursue education that is socially just and agree with recent arguments that a practice based approach to social justice teacher education must put at the forefront critical pedagogies that attempt to disrupt historical inequities and systemic oppression ingrained with our education system (Philip, Souto-Manning, Anderson, Horn, Carter-Andrews, Stillman, & Varghese, 2018). Within our video analysis, there was little evidence that teachers centered students' ideas, lived experiences, and histories or designed their lessons with the needs and assets of the students, families, and communities they serve despite these ideas being central to the teaching framework and teacher education program mission. This is not to say that these teachers did not do this, but that it was not evidenced in the whole class discussions we analyzed. To us, this is a missed opportunity in that whole class discussions provide opportunities to disrupt traditional notions of classroom authority and expertise by positioning students as constructors and evaluators of scientific claims (Ford, 2008). In addition, whole class discussions are opportunities for students to share and position their ideas, experiences and histories as valuable within the classroom potentially providing space for alternate ways of knowing and knowledge outside of traditional western canonical science ideas and practices (Madkins & McKinney de Royston, 2019; Rosebery et al., 1992). This calls on teacher educators and preparation programs concerned with promoting social justice science education to consider what are the structures and practices that support science teachers in centering students' capacity to disrupt systemic oppression and historical inequities and participate in rigorous science practice.

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