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Science and Mathematics Teachers Working Toward Equity Through Teacher Research: Tracing Changes Across Their Research Process and Equity Views

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Abstract We investigated secondary science and mathematics teachers engaged in a two-and-a-half-year professional development effort focused on equity. We examined how teachers conducting research on their own instructional practices—a central learning strategy of the professional development project—informed and/or constrained their views related to three strands of equity: teachers and teaching, students and learning, and students' families and communities. Data collected included recordings of professional development seminars and school-site meetings, three sets of individual interviews with teacher researchers, and drafts and final products of the classroom research teachers conducted. From our qualitative analyses of data, we found that most teachers addressed at least two of the three equity strands in researching their own practice. We also found that most transformed their understandings of teachers and students as a result of their teacher research process. However, teachers' views of families and communities changed in less substantive ways. We close with recommendations for other researchers and professional developers intent on supporting science and mathematics teachers in using teacher research to work toward equity.

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Introduction

Reform documents in science and mathematics education call for practicing teachers to interrogate their understanding of equity and to transform their classroom practices so that *all* students can excel in these disciplines (National Council of Teachers of Mathematics, 2000; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; National Research Council [NRC], 2012; NGSS Lead States, 2013). Many science and mathematics teachers, however, are unable to translate the recommendations set forth in reform documents into equitable curricular and instructional practices on their own (Bianchini & Brenner, 2010; Carlone, Haun-Frank, & Webb, 2011; Gutiérrez, 2012). For example, some teachers hold deficit views of underserved students that interfere with their ability to teach them: They believe that students from culturally diverse and/or low socioeconomic backgrounds are less capable (Aguirre, 2009; Bryan & Atwater, 2002) or have large gaps in the knowledge and experiences they bring with them into the classroom (Gilbert & Yerrick, 2001; Nasir, Hand, & Taylor, 2008). Such practicing science and mathematics teachers would benefit from participation in professional development opportunities that focus on issues of equity.

Equity professional development efforts, in turn, prove challenging to effectively implement. To adequately support science and mathematics teacher learning, such efforts must include sustained work, tolerance for the complexities of equitable teaching, and multiple strategies for personal exploration and professional growth (Bianchini & Cavazos, 2001; Lee, Lewis, Adamson, Maerten-Rivera, & Secada, 2008; Llosa et al., 2016; Mensah, 2013; Rivera Maulucci, Brotman, & Fain, 2015; Rodriguez, 2015). Equity professional development efforts that include a teacher research component must also ask teachers to start from the lives and experiences of their students (Calabrese Barton et al., 2012; Khisty, 1995) and to situate their investigations in local practice (Blumenreich & Falk, 2015).

In this study, we investigated secondary science and mathematics teachers engaged in a two-and-a-half-year professional development opportunity (implemented in 2003–2005) focused on issues of equity. More specifically, we examined how researching one's own instructional practice—a central learning strategy of the professional development effort—informed and/or constrained teachers' views of three strands of equity: teachers, students, and students' families and communities. Our study was guided by two research questions: (1) How did teacher participants' research questions, methods, and findings change over the course of the professional development project? (2) How did engagement in this teacher research process influence teachers' views of themselves, their students, and their students' families and communities in relation to equity? Our purpose in answering these questions was to contribute to conversations about the strengths and limitations of using

teacher research to engage science and mathematics teachers in the complex and uncertain work of learning to teach toward equity.

Conceptual Framework

In this study, we viewed teacher learning as a process of enculturation into a community of practice (Putnam & Borko, 2000). Both our conceptual framework, discussed here, and the model of professional development, presented later, were fashioned from two bodies of scholarship: definitions of teacher research and descriptions of educational equity.

Teacher Research as a Way to Promote Equity

Teacher research has long been recommended as a way for teachers to improve their instructional practice, their students' learning, and their larger "educational situation": To "identify areas for improvement, if not transformation, … and [to] address them through the practice of inquiry, action, reflection, and learning" (Capobianco & Feldman, 2010, p. 909). Hubbard and Power (1993) described teacher research as using classrooms as laboratories and students as collaborators to look systemically at and change the processes of teaching and learning. They recommended teachers begin with "wonderings worth pursuing" and then work to transform such wonderings into researchable questions (p. 2). Cochran-Smith and Lytle (2009) clarified that teacher researchers be viewed both as *knowers* and as *agents* for educational and social change. Noffke (1997, 2009) underscored that with its long ties to democratic forms of education, teacher research should be understood as a way for teachers, individually and collectively, to identify and begin to address inequities that exist in schools.

The decision to design and research an equity professional development project centered on teacher research was informed by the work of other science education scholars intent on promoting equity. Rosebery, Warren, and colleagues (Rosebery & Puttick, 1998; Rosebery & Warren, 1998) conducted and researched a 4-year effort among teachers, educators, and scientists to better understand both scientific inquiry and students' learning of science—to help *all* students make better sense of scientific ideas and practices as a result. Feldman, Bennett, and Vernaza-Hernandez (2015) emphasized that facilitating teachers' action research projects on equity was challenging: Although teachers were expected to pursue justice through research, their efforts were constrained by the very educational system they were attempting to transform.

Descriptions of Educational Equity

Scholars have provided numerous descriptions of what should count as educational equity (Banks, 2014; Cochran-Smith, 2003; Secada, 1994, 2008; Sleeter & Grant, 2009). This study employed two different, but complementary equity definitions. In the professional development context, because equity was

understood as tightly tied to school contexts and the needs and interests of students in them, professional developers asked teachers to read and discuss a range of scholars concerned with equity issues. Readings included Kohl (1994), McIntosh (1995), Nieto (1999), Secada (1994), Sleeter and Grant (1999), and Weissglass (1998). Discussions addressed the range of equity definitions held by teachers, from equity as the same treatment for everyone to equity as compensation for social injustice (Secada, 1994); white and male privilege (McIntosh, 1995); students' funds of knowledge (North Central Regional Educational Laboratory, 1994); the influence of social class on education (Weissglass, 1998); and reasons for students' resistance to learning (Kohl, 1994). From readings, discussions, and activities, teachers fashioned their own equity definitions situated in and responsive to the needs of their students, schools, and communities.

For this study, we narrowed the equity ideas examined in the professional development context to conceive of equity as composed of three strands: (a) teachers and their teaching, (b) students and their learning, and (c) home and community contexts. In essence, we defined equity as teachers acting as agents of change to meet the needs of their students in the multiple contexts of school, family, and community. We elaborate on each of these three strands below.

One, advocates of equity call for teachers to see themselves as change agents who can work to achieve science and mathematics for all (Anderson, 2010; Cochran-Smith & Lytle, 2009; Darling-Hammond, French, & Garcia-Lopez, 2002). Teacher agency begins by adopting the stance of a learner: Teachers are asked to learn from their teaching and in turn teach from their learning (Lippincott, 1999). Aikenhead and Jegede (1999) suggested teachers act as guides between their discipline and students' everyday lives, devising ways to assist students in crossing borders that separate these sometimes disparate worlds. Delpit (1988, 2010) recommended teachers implement instructional strategies effective in helping students both navigate the foreign terrain of a discipline as it currently exists and those useful in refashioning the discipline in and through their own cultures and communities. Kumashiro (2001, 2015) underscored the importance of teachers encouraging students to critically question the science and mathematics they are asked to learn: What aspects of these disciplines are students open and resistant to learning? How might scientists and mathematicians be open or resistant to asking certain questions, using certain methods, or communicating certain findings? Where might students turn to imagine other ways of doing science or mathematics? Further, Yerrick, Schiller, and Reisfeld (2011) urged teachers to develop relationships with students based on rapport and respect.

Two, transitioning from discussion of teachers and teaching to students and learning, teachers intent on teaching science and mathematics to all are asked to start curriculum and instruction from the lives, interests, and expertise of their students (Calabrese Barton et al., 2012; Khisty, 1995). To do so, teachers must see their students both as individuals and as members of diverse gender, cultural, socioeconomic, and linguistic groups (Bianchini et al., 2000; Nieto, 1999). They must understand that students, both intentionally and unconsciously, exercise agency in their sense making, discourse, and actions and that this agency is shaped by larger structures (Carlone, Johnson, & Scott, 2015). At the intersection of agency

and structure, students construct and enact multiple identities (e.g., discursive, gender, ethnic, and academic) in and outside of the classroom (Brickhouse, Lowery, & Schultz, 2000; Brown, 2006; Nasir, 2002). Teachers must recognize that, to learn science and mathematics, students must not only construct disciplinary knowledge but develop an identity as a competent learner as well (NRC, 2012).

Three, researchers have found that the larger contexts of school, families, and communities promote or constrain teachers' efforts to engage all students in meaningful disciplinary learning. McGinnis, Parker, and Graeber (2004) concluded that teachers' perceptions of their school culture—their views of their school's affordances, constraints, and demands—influenced their decisions to implement science and mathematics curricular and instructional reform in their classrooms. Moll, Amanti, Neff, and Gonzalez (1992) recommended science and mathematics teachers identify, celebrate, and use the diverse funds of knowledge present in their students' homes and communities as resources to transform their curricular and instructional practices. Chinn (2007) and Kisker et al. (2012) recommended teachers to connect students to their sense of place by examining local indigenous knowledge and practices.

Research Design and Methods

The Professional Development Context: TEMSE

Teaching for Equity in Mathematics and Science Education, or TEMSE, was a professional development effort designed for teachers from schools considered high need. The project ran for two-and-a-half years, from January 2003 to June 2005. Among teachers and professional developers, TEMSE attempted to create a critical learning community, where issues of equity and diversity were placed front and center (Cochran-Smith & Lytle, 1999; Nieto, 1999). To deepen and broaden teachers' understanding of equity, the project implemented four strategies for professional learning (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010).

One professional learning strategy, the strategy foregrounded in this study, was teacher research. Teacher research was made central to TEMSE because it promotes reflection on, local knowledge about, and transformation of curricular and instructional practices (Capobianco, 2007; Cochran-Smith & Lytle, 2009). The ways TEMSE provided teachers a thorough grounding in and support for their research satisfied the four assertions for *quality* outlined by Capobianco and Feldman (2010). Readings, discussions, and activities about teacher research (e.g., Hubbard & Power, 1993) in interaction with equity issues (e.g., Nieto, 1999; Sleeter & Grant, 1999) guided teachers both in constructing their own definitions of equity situated in their lives and work and in using their equity definitions to inform their teacher research projects. Each teacher, or in one case, a pair of teachers, crafted a researchable question connected to equity concerns, collected and analyzed data from her or his own classroom, shared findings with other TEMSE teachers and professional development team members, and iteratively revised her or his research process in light of new questions raised. Each teacher researcher received ongoing

assistance from a faculty and/or graduate student mentor. In the project's second year, teachers presented findings from their research at a state or international teacher research conference.

Three additional professional learning strategies were included in TEMSE as well. As the second strategy, through participation in dyads and personal experiences panels, teacher participants interrogated their own and others' experiences with inequities in society, in general, and in science and mathematics education, in particular (Weissglass, 2000). Because educational inequities arise from systematic injustices as well as personal prejudices, as the third professional learning strategy, teachers worked to understand patterns in school, district, and national demographic and achievement data and to determine how policies and achievement measures differentially impacted groups of students (Confrey, Makar, & Kazak, 2004; White & Anderson, 2012). Finally, as the fourth strategy, teachers engaged in reform-based science and mathematics activities as learners and then considered how to implement these instructional approaches in their own classrooms (Lee & Fradd, 1998; Rosebery & Warren, 2008).

These four strategies for professional learning about equity were distributed across four types of structures: whole group professional development seminars, school-site meetings, individual research consultations, and teacher research conferences. Professional development seminars, the first structure, were held at the university. There were 22 seminars in total, each lasting 6–7 h. School-site meetings, the second structure, were convened at individual schools; only teachers from that school attended a given meeting. During these 2-h meetings, teachers were supported in their efforts to translate classroom concerns into questions to guide their teacher research projects. Three such meetings were held at each of the three schools during the first year of the TEMSE project. As teachers began their research efforts in earnest, site meetings were replaced with the third structure, individual research consultations. For consultations, teachers selected a faculty and/or graduate student mentor to help support them in their research efforts. Consultations occurred whenever teachers requested assistance. Finally, as the fourth structure, teacher participants presented their research findings at either a state or international teacher research conference in the second year of TEMSE. (For additional information on strategies and structures, see Bianchini et al., 2015.)

Teacher Participants, Professional Developers, and Researchers

Twelve experienced science and mathematics teachers initially participated in the TEMSE professional development project (see Table 1). These 12 constituted three teams of four teachers from two middle schools and one high school in southern California (see Table 2). Each school was situated in a different small city, was considered low achieving, and had large Latina/o and ELL student populations (California Department of Education, 2004). Over the course of the professional development project, five teachers withdrew their participation (see again Table 1). For this paper, we decided to focus our analysis on the seven teacher participants who completed TEMSE: one African-American woman, one African-American

Table 1 Teacher participants' background information

Teacher participant	School	Subject(s) taught	Teaching experience (years)	Ethnicity and gender	Time in TEMSE (years)
Brent	De La Vina	Science	20	European American male	2.5
John	De La Vina	Mathematics	39	Asian-American male	2.5
Trisha	De La Vina	Science	5	European American female	2.5
Walter	De La Vina	Mathematics	3	Asian-American male	Left after 1.5
Desiree	John Muir	6th grade[a] (science and mathematics)	20	African-American female	2.5
Diane	John Muir	Mathematics	11	European American female	Left after 1.5
Michelle	John Muir	Science and mathematics	10	European American female	2.5
Shawn	John Muir	6th grade[a] (science and mathematics)	6	African-American male	2.5
Bill	Prairie	Science	7	European American male	Left after .5
Marcella	Prairie	Mathematics	7	Latina	Left after .5
Rachel	Prairie	Science	13	American Indian female	Left after .5
Suzie	Prairie	Mathematics	14	European American female	2.5

[a] Sixth grade teachers taught all subjects, including science and mathematics. All other teachers taught courses specific to science and/or mathematics in grades 7–12. Teachers who were included in the analyses have their names in bold font

man, one Asian-American man, three European American women, and one European American man.

In addition to the 12 teacher participants, TEMSE began with 12 professional development team members. Team members included science and mathematics education faculty, professional developers, postdoctoral scholars, and graduate students; they represented both genders and diverse ethnicities (African-American, Asian-American, European American, and Latina/o). Over time, six team members left the project and five new members joined.

Finally, three researchers analyzed the data presented here. The first and second authors were part of the TEMSE professional development team; the third author was not. Two were mathematics educators and one, a science educator. All three were European American women.

Table 2 Demographic information about participating schools

School	Student enrollment	Students by ethnicities	ELL students (%)	Students on free/ reduced lunch (%)
De La Vina middle school	557 7th and 8th graders	85% Latina/o 12% European American 2% African-American 1% American Indian or Alaska Native	56	66
John Muir middle school	1203 6th–8th graders	72% Latina/o 17% European American 5% African-American 3% Filipino 1% each American Indian or Alaska Native, Asian-American, and Pacific Islander	20	62
Prairie high school	2948 9th–12th graders	79% Latina/o 13% European American 4% Filipino 2% African-American 1% Asian-American	35	44

Data presented are from 2003 to 2004, the first year of the TEMSE project

Data Collection and Analysis

To answer our two research questions, we collected three types of data. To trace changes in teachers' research questions, methods, and findings, we collected teachers' research documents: drafts and final copies of teachers' research projects (e.g., research posters, PowerPoint presentations, and written reports), as well as samples of their classroom data (e.g., student surveys, videos of focus group interviews, and videos of classroom instruction). We also recorded all professional development seminars and school-site meetings. We used two video cameras to capture each of the 22 seminars, recording approximately 200 h of video in total, and used two audio recorders to capture each of the nine school-site meetings, recording approximately 30 h of audio in total. Most of these data collected explicitly documented and/or identified changes teachers made to their curricular and instructional practices.

To determine how engaging in teacher research influenced their understanding of three strands of equity (e.g., teachers, students, and students' families and communities), we conducted individual interviews and collected written reflections. Each teacher was interviewed three times: at the beginning of the project, during the first summer institute, and during the second summer institute. In their initial interview, teachers shared their professional history, goals for the professional development project, and understandings of equity issues situated in their classroom and school contexts. In subsequent interviews, teachers shared their views about the

professional development process, their evolving understanding of equity, their progress on their individual research projects, and resulting changes to their instructional practices. In their written reflections, completed near TEMSE's close, they discussed changes both in their understanding of equity and in their instructional practices, as well as their future professional plans.

We drew from Saldaña (2013) to structure our two cycles of qualitative analysis. Our first analytic cycle answered our first research question; it proceeded in three phases. In phase one, we transcribed a purposeful sample (Patton, 2002) of videotaped professional development seminars. We selected 5 sessions from each of the four strategies for professional learning (teacher research, personal experiences, analysis of data, and engagement in instructional approaches), ensuring that for each strategy the five sessions spanned the time range of the entire project, contained sustained discussion of equity, and included a final teacher reflection activity. We also transcribed all audiotaped individual interviews and those parts of the audiotaped school-site meetings where teachers shared their ideas for their research projects. In phase two of our first analytic cycle, we then examined professional development transcripts, interview transcripts, and teachers' written products to track the evolution of teacher participants' research over time and to make visible similarities and differences across their projects. For each of the seven teacher participants, we organized the data on his or her research questions, methods, and findings into three stages: *initial wonderings* (see again Hubbard & Power, 1993), *formal research*, and *next research steps*. In the third and final phase of this first cycle, we determined how each teacher's research resonated with the three strands of equity discussed in our conceptual framework above: teachers and teaching, students and learning, and students' families and communities.

In our second analytic cycle, to answer our second research question, we examined how participation in teacher research reinforced, challenged, and/or transformed teachers' views and reported practices. We constructed tables for each teacher participant on the following topics tied to her or his research: teacher research, views of equity, reported instructional practices, views of and interactions with students, and views of and interactions with families and communities. We then looked within and across teachers and time to discern patterns and discontinuities (see Spradley, 1980) in the ways teachers' research promoted or constrained their understanding and reported practices related to our three equity strands: teachers, students, and students' families and communities. We emphasize that teachers' views and reported practices were only linked to their participation in teacher research if teachers themselves explicitly stated this connection.

Across analytic cycles, we ensured trustworthiness (Brenner, 2006) in multiple ways. One way we did so was by checking transcripts against their original recordings. As a second way, for a given phase or cycle of coding, the three researchers collectively designed the coding scheme, applied it to a sample of the data, made modifications, and practiced coding with additional samples until reliability was reached. Then, two coders independently applied the coding scheme to each piece of data and resolved differences through discussion. A third way we ensured trustworthiness was keeping track of all analytic decisions made

through a detailed audit trail (Guest, MacQueen, & Namey, 2012). Below, we present our findings in two parts.

Findings Set 1: The Evolution of Teachers' Research

In this first set of findings, to answer our first research question, we present changes in teacher participants' research over time. We organized this section by the three stages of teacher research discussed above: initial wonderings, formal research, and next research steps.

Initial Wonderings

Over the course of the first several professional development seminars and school-site meetings, teachers worked to formulate their research plans. In their initial wonderings, six of the seven teacher participants (all but Suzie) attended to one or more strands of equity (see Table 3). More specifically, all six proposed investigating some aspect of students and their learning. Five of these six (all but Shawn) included teachers and teaching in their wonderings as well. None, however, included attention to students' families and communities. We caution that, at this early stage in the project, three teachers (Brent and Trisha, who worked together, and Michelle) framed inequities from a deficit student perspective. We also note that, for some teacher researchers, there was a gap between their initial wonderings and their tentative research designs: From a careful read of the second and third columns of Table 3, the strands of equity teachers intended to investigate were not always visible in their initial set of research questions.

In his initial wonderings, for example, Shawn proposed researching low-income students who participated in his school's weeklong fieldtrip to an informal science education camp—to attempt to determine whether such an experience enhanced these 6th grade students' interest and achievement in science. As a 6th grade teacher involved in organizing this informal experience, he wondered: "Do extracurricular/enrichment programs in science, such as Outdoor School, make a difference in students' interest and achievement in science? What can be done for students who are unable to afford tuition for Outdoor School science camp?" Shawn's wonderings explicitly included an equity focus on students and their learning.

Formal Research

Moving from teachers' initial wonderings to their formal research projects, we found that five of the seven teacher participants maintained an explicit focus on equity (see again Table 3). Suzie added equity in her formal research stage, while Michelle let equity drop away. As with their initial wonderings, all six teachers who included an equity focus in their formal research investigated students and their learning. All six also included examination of teachers and their teaching. Further, at some point in their formal research process, five of the six (all but Suzie) stated their intent to learn more about their students' families and communities.

Table 3 A comparison of teacher researchers' initial wonderings, formal research questions, and next research steps

Teacher researcher	Initial wonderings (March 2003)	Research has equity focus?	Formal research question(s) (April 2004)	Research has equity focus?	Next research steps (May 2005)	Research has equity focus?
Brent and Trisha	"Why is the return rate of assigned science homework so low? What role does homework have in the science curriculum? Is homework beneficial for the students or teachers? Do teachers have to assign it at all? Is low homework return rate a cultural problem? What influences are involved?"	Yes	"Why are so many students at De La Vina Middle School failing science and what can we, as science teachers, do to increase the success of our students?"	Yes	Brent: Planned to continue with Trisha the "action research project on our own to compare student success and equity at our school" Trisha: Planned to continue to "do research about best science [instructional] practices with an emphasis in equity"	Yes
Desiree	"How do story problems (word problems) limit access to math and science? Why do students have a hard time understanding the context of the problems? How can I, as the teacher, improve or help students who have difficulty with word problems?"	Yes	"How [do I] improve students' ability in solving word problems? Does integrating science, history, and literature in math instruction promote students' interest?"	Yes	Planned to continue to "rethink how I teach math and science—allowing each student to contribute important ideas that promote diversity." Also planned to attend graduate school to continue her research.	Yes

Table 3 continued

Teacher researcher	Initial wonderings (March 2003)	Research has equity focus?	Formal research question(s) (April 2004)	Research has equity focus?	Next research steps (May 2005)	Research has equity focus?
John	"Why has the CPM [College Preparatory Mathematics] math curriculum been successful with high-achieving kids? Will the three techniques (cooperative learning groups, mastery over time, and spiral approaches) from CPM work for the low achieving students (under 40% on standardized tests), especially Latino students? Will there be enough materials to spread out the curriculum to the lower math learners? How can the concepts be traced as they spiral back to the students to detect the point where they "click-in" for understanding?"	Yes	"Within the context of a mathematics reform curriculum, does the acquisition and use of more complex mathematical language in ELD [English Language Development or ELL] students indicate a conceptual understanding and thereby lead to mastery of the mathematical content?"	Yes	Because he was retiring, offered no future research plans.	N/A
Michelle	"How do I get students out of their habit of 'not doing'? How can I close the achievement gap in my class? What are students' reasons for 'not doing' or learned helplessness?"	Yes	"How do different teaching strategies influence student motivation (connection) to learn math and science?"	No	Planned to "look into more and different ways to continue to promote equity among my students and colleagues." Planned, in particular, to research "the parent component." Stated that "equity has become very much a part of who I am. … It's a must"	Yes

Table 3 continued

Teacher researcher	Initial wonderings (March 2003)	Research has equity focus?	Formal research question(s) (April 2004)	Research has equity focus?	Next research steps (May 2005)	Research has equity focus?
Shawn	"Do extracurricular/enrichment programs in science, such as Outdoor School (6th grade science camp), make a difference in students' interest and achievement in science? What can be done for students who are unable to afford tuition for Outdoor School science camp?"	Yes	"How does attending a residential science school affect the attitudes, expectations, and performances of sixth grade students before and after the experience?"	Yes	Planned to use "data resource gathering tools, such as surveys, interviews, and audiotaping, to assess and analyze student and teacher needs in the classroom." Also "endeavor[ed] to be part of future research-oriented groups with equity as a control or significant concern"	Yes
Suzie	"Looking at previous success in math classes and noticing the link between attendance and homework, how can I improve student success in completing and turning in homework? How can I build a sense of ownership for learning in my students? How can visualization and organization techniques be used to help students complete assignments?"	No	"How does an organized homework system help high, middle, and low achieving students' competency in basic math? And is there a subgroup which benefits greatly from the system?"	Yes	"Involved in the teacher's network with the leadership institute." Engaged in a new research project to compare the impact of two different mathematics curricula on students' standardized test scores	No

(1) We collected two versions of teachers' formal research questions: one from their August 2003 summer poster created for the TEMSE institute and one from their April 2004 research poster presented at a teacher research conference. Here, we present those from April 2004. (2) Teachers' quoted initial wonderings, formal research questions, and next research steps did not always explicitly include mention of equity. To provide clarity, then, we added the research has equity focus column for each stage

Extensions (or not) of Initial Wonderings

We found that three of the seven teacher participants' formal research projects (Desiree, Shawn, and Suzie) emerged as clear extensions of their initial wonderings. The other four (Brent and Trisha, John, and Michelle) developed projects that differed from their wonderings in substantive ways. As an example of the former, from the beginning of TEMSE, Desiree decided to focus her research on mathematics word problems. In her interviews, she emphasized that "to be successful in math, all students need to be able to solve word problems." Because "students identify word problems as the most difficult aspect of sixth grade math," for her inquiry, she implemented a range of reform-based, student-centered instructional strategies to determine which were effective in engaging all of her students in making sense of word problems and in facilitating their perseverance in solving them. She integrated science, history, and literature into mathematics word problems; connected word problems to students' everyday lives, for example, creating a store in her classroom where students calculated the sale prices of merchandise; invited gifted and talented education (GATE) students and other teachers to visit her class to engage her students in word problems; redesigned her instruction so that students completed word problems in class rather than for homework; and asked students to devise their own word problems and then have their peers solve them. Desiree collected a range of data to determine how these diverse instructional strategies shaped her students' efforts to solve word problems: She administered student and teacher surveys, examined students' mathematics journals, and collected samples of students' written work (e.g., creative story problems, drawings, and solutions to textbook problems). She found that her efforts indeed allowed her students to better engage with and solve word problems, in particular, that her students benefited from writing and solving each other's word problems.

As an example of the latter, Brent and Trisha, who worked together on their research, initially wondered about homework: if homework was "beneficial" to students or teachers, if students' low homework return rates were "a cultural problem," and if they should "assign it at all." As they processed initial survey data from their students, however, they began to see that both students and their parents cared about succeeding in school.

Trisha: We did a survey and one of the questions was … Does your parent even care what your grades are? Do you get in trouble if you get bad grades? And all of them [the students] were marking, "It's very important to my parents. This is a major requirement. My parents really do care."

Brent: [They also wrote,] "I [as a student] really care [as well]."

In response to these survey findings, Brent and Trisha expanded the scope of their investigation beyond homework, dropped the idea that culture was a "problem," and began to focus on changing their own practices rather than those of their students. By August of Year 1, they had fashioned their formal research questions to ask: "What factors do we as teachers/educators have control over that most strongly

influence student achievement? What modifications can we make to our teaching methodologies to improve student achievement based on our research?"

Focusing in on Formal Research Questions

As with their initial wonderings, we also found that teacher participants' formal research questions did not always fully capture the depth and breadth of their formal research process. There were gaps between questions and process in relation both to equity, in general, and students' families and communities, in particular.

In relation to equity concerns, we found that although six teacher participants integrated equity into their formal research design and analyses, only two (John and Suzie) explicitly included an equity focus in their research question(s). For example, in his formal research, John decided to investigate his ELL students' learning of mathematics—to examine the possible synergistic relationship between communicating mathematics in English and mastering mathematics concepts. He asked: "Within the context of a mathematics reform curriculum [College Preparatory Mathematics], does the acquisition and use of more complex mathematical language in ELD [ELL] students indicate a conceptual understanding and thereby lead to mastery of the mathematical content?" To answer this question, John focused his investigation on ELL students' learning of one mathematics content standard: finding and graphing the coordinate pairs of a linear and nonlinear equation. Students were audiotaped and videotaped working in dyads on the same two graphing problems at two points during the school year. These tapes were transcribed and coded for (a) "key use of mathematical vocabulary," both in Spanish and in English, and (b) "key mathematical sentences and phrases"—"for signs of increased usage and complexity between the two cycles." John found that, over time, ELL students increased their English language complexity and were able to demonstrate mathematics content mastery.

In relation to the third strand of our equity framework, students' families and communities, only one teacher (again, John) explicitly referenced parents in his formal research questions. John included a question about parental expectations in his August 2003 summer poster: "Can parental expectations lead to an increase in the frequency and quality of the mathematical language used by Latino students?" However, he later dropped this question in his April 2004 research poster. While John never collected data related to parents, four other teachers (Brent and Trisha, Desiree, and Shawn) did. For example, as part of Shawn's research on ways to increase the participation of low-income students in an outdoor science camp, he asked students what their parents thought about their achievement in science and mathematics. To be clear, however, no teacher collected data directly from family or community members.

Ignoring Equity in Formal Research

To conclude this section, we found that Michelle was the only teacher participant who neither tied her formal research question nor her formal data collection and analytic processes to equity issues. Although Michelle had included an equity

component in her initial wonderings, she did not do so in her formal research question: "How do different teaching strategies influence student motivation (connection) to learn math and science?" To answer this question, Michelle implemented a variety of student-centered instructional strategies in her classroom, such as centers, think-pair-share activities, and cooperative learning groups. She collected data from her students after she implemented each activity, using written reflections and focus group interviews to do so. However, as with her formal research question, issues of equity never entered into her data collection or analytic processes. Indeed, over time, the concept of *learned helplessness*, which had been introduced in her wonderings but had receded into the background while exploring different types of instructional strategies, reemerged as her central focus. It is important to clarify that although learned helplessness can be connected to equity (see Kohl, 1994), Michelle understood learned helplessness to be the result of students' laziness, parents' interference, and/or cultural norms.

Next Research Steps

In next steps, the last stage of their TEMSE teacher research projects, we found that six of the seven teacher participants expressed an intention to continue with or expand their formal research activities. John, who retired at the end of TEMSE, was the only teacher who did not plan to do so, perhaps because he would no longer be in the classroom. Five of these six teachers (all but Suzie) explicitly stated that they would continue to make equity a focus in their next steps. Three (Brent and Trisha, and Michelle) described future research plans that would examine not only teachers and students in relation to equity concerns, but families and communities as well.

Brent, for example, intended to continue to research teachers, students, and families and communities in relation to equity concerns. During his final research presentation, held at the close of TEMSE, Brent posed three future research questions he planned to investigate.

> [One,] how do we modify our curriculum to promote equity so that we don't have all the white kids getting good grades and all the other kids getting low grades? … [Two,] how do we increase the motivation of the students so they want to be successful? … And [three,] how do we get our communities involved?

Brent's first question focused on teachers and teaching; his second, on students and their learning; and his third, on students' families and communities.

In contrast, Suzie, the one teacher who began a new teacher research project before the close of TEMSE, did not explicitly attend to equity issues as part of this effort. This was despite the fact that her formal research project on the relationships among students' organization of their mathematics notebooks, homework completion, and grades had included an equity component. Suzie had joined a teacher leadership network that supported teachers in conducting and disseminating their own research. For her new research project, Suzie compared the impact of two reform-based mathematics curricula on students' standardized test scores.

Findings Set 2: Changes in Teachers' Views Related to Equity

To answer our second research question, we examined changes (or not) in teachers' views and reported instructional practices as a result of their engagement in research. We organized these changes using the three strands of equity discussed in our conceptual framework.

Teachers' Views of Themselves as Central to Teaching and Learning

As a result of their research experiences, we found that six of the seven teachers (all but Michelle) came to see themselves as more powerful agents in the teaching and learning process, particularly for their underserved students. Changes in their views of teachers' roles and responsibilities appeared to be sparked by greater attention to and reflection on students' needs, opinions, and academic performance. Their new perspectives emerged from and contributed to changes in planning, classroom interactions, and instructional activities tried out during their research projects. With their greater sense of agency, teachers reported expanding and improving the opportunities they provided students at both the classroom and school levels.

John, for example, became a more active facilitator of student engagement and learning at the classroom level. He entered TEMSE having implemented reform-based mathematics instruction for decades: As chair of his middle school's mathematics department and as a professional developer for an innovative mathematics curriculum, he prided himself on attempting to address equity issues through instruction and on helping his department colleagues to do the same. However, his investigation of ELLs' development of mathematical fluency made clear to him "that I've been cruising for a long time." He elaborated, "If I'm ever going to get all kids to this point [of mastering the mathematics standards,] th[en] I have to change the way I do things, the way I look at kids, the way I think." Indeed, John was the most explicit of the six participants in his description of teachers as central to achieving science and mathematics for all: "I always believed that every kid can do it. … But I see now the more important role the teacher has to play in this process. … I think the key is that, the teacher." He emphasized: "[Equity is] not going to happen unless there's some changes that take place in the teaching."

As a second example, as a result of his joint research project with Trisha, Brent worked to change the opportunities he provided students to learn science not only at the classroom level, but at the school level as well. Brent successfully argued for the reinstatement of a school-wide homework advisory period and an after school homework club.

> Two years ago when they cancelled that [the homework club], I just let it slide. But now I can use this stuff [my research] I'm learning from this class [the professional development project] to kind of push it and feel more confident.

Brent stressed that engaging in teacher research gave him the courage and expertise he needed to advocate at the school level for homework support.

Teachers' Views of Students as Willing Participants

We also found that six of the seven teachers (again, all but Michelle) revised their views of students as a result of engaging in research. Changes in teachers' understanding of students emerged along two dimensions: They grew to see their students both (a) as willing to learn and (b) as eager to help improve the teaching and learning process.

Brent, Trisha, Desiree, and Suzie began their research, assuming that at least some of their students were resistant to learning. Examination of students' responses to surveys and interviews, however, prompted them to change their view of students—from being resistant to learning, to needing additional support and scaffolding to succeed. They found that students would often complete their work once they knew what the teacher expected and/or how to perform the task. In her study of interactions among organization, homework, and grades, for example, Suzie found that her mathematics students improved their organizational skills with explicit instruction and support. Suzie noted: "I actually would sit down with students and go through their notebooks with them one-on-one.… Once we sat down and organized and I was checking it, they stayed organized. …There was some pride in their notebooks now that they had them organized." Students' completion of homework and their grades in the course improved as a result; a statistical analysis of students' grades by different subgroups (e.g., gender, ethnicity, first language, and free or reduced lunch status) found that Latino students benefited the most from this new system. We note that the TEMSE professional development team had expected Suzie to examine a more substantive instructional issue than that of homework for her teacher research project, but that Suzie decided against reworking her line of research.

Through their research, Brent, Trisha, John, and Shawn also learned that their students were eager to provide suggestions about ways to improve the processes of teaching and learning. Shawn, for example, had extended his investigation on facilitating students' participation in an outdoor science camp to revising the ways he taught science in his own classroom. He described his students' eagerness to provide him feedback on his attempts to implement new instructional strategies:

> When you're working with them [students], I think what you're actually trying to do is trying to understand through them really what does work and what doesn't work. … And the students will tell you whether it's something that they really liked or not. And they will. They will tell you.

Students told him, for example, that they enjoyed working with their hands to learn science, so "we built models of whatever they wanted to. Animals, we did at first. And then we built models of houses." In brief, Shawn's students not only provided him with data to help answer his formal research question, but with suggestions to help him improve his teaching as well.

Teachers' Views of Parents as Valuing Education But Needing More Information

Finally, we found fewer changes in teachers' views of families and communities. By the end of the project, five teachers (Brent and Trisha, Desiree, John, and Shawn) understood that their students' parents valued education, while two (Suzie and Michelle) retained deficit views. However, none of the teachers came to see families and communities in ways expected by the professional developers—as vital resources for and integral members of classrooms and schools (see Hammond, 2001).

More specifically, five teacher participants (all but Suzie and Michelle) understood or came to understand that parents value education, but that they may lack the knowledge or experiences needed to adequately support their children's success in school. Three of these five (Desiree, John, and Shawn) entered TEMSE already with this view. In her initial interview, for example, Desiree described how it was her responsibility as a teacher of color and as a teacher of predominantly underserved students to provide encouragement and opportunities to succeed, despite the fact the lack of support students might experience from their parents and the larger society.

> I look out into my classroom and I see the brown faces. … I want them to know, "You can do math." … I know how society has treated these [students]. These students are sometimes misrepresented in our society. I've always tried to encourage them. "You can do this. If you need help, I'm here. If your parents can't do it, you have to get it."

Desiree's research project reinforced her idea that parents could not always support their children in completing schoolwork. After reading students' responses to surveys and reflections in mathematics journals, she decided to stop assigning students word problems to complete at home. As she explained in the final TEMSE seminar, she found that "they [students] are not able to do them [word problems at home] and they can't get help from parents."

In contrast, from the beginning to the end of TEMSE, Michelle and Suzie retained more negative views of parents than the other five teacher participants. Michelle, in particular, saw parents as problematic. In the early months of TEMSE, Michelle described many of her students and their parents through a deficit lens. Students exhibited learned helplessness, in part, because of their overly busy parents; parents who did not allow their students to learn things on their own were one of the causes of learned helplessness. At the close of TEMSE, Michelle stated her intent to further research "the parent component" of the learned helplessness triangle.

> This [TEMSE] is not an end for me at all, because it's like looking for the cure for cancer. It's going to be a process looking for the cure for learned helplessness. … I want to look into a parent component, because I feel like I'm a triangle. I feel it's teacher-parent-student. … I don't think anybody's doing anything about the parents.

For Michelle, parents remained a barrier to their students' success in school.

Discussion and Implications

We begin our discussion by emphasizing that little research on engaging practicing science and mathematics teachers in professional development tied to equity exists (as an exception, see again Feldman et al., 2015); most studies about teacher research and equity issues are situated at the preservice level (e.g., Athanases, Wahleithner, & Bennett, 2012). As such, our study provides new insights into the benefits and challenges of using teacher research to deepen experienced secondary science and mathematics teachers' understanding of equity. Indeed, our findings support the claim we made in our introduction—that professional development about equity is complex and challenging for teacher participants and professional developers alike.

The Benefits of Teacher Research

Our investigation of changes in teacher participants' views and reported practices as a result of their engagement in equity teacher research yielded two key strengths: As expressed in discussions of their research and as documented in their research products, most grew in their understanding of teachers and students in relation to equity. More specifically, one strength, described by John and Brent in our second set of findings, was that teachers grew to see themselves as both teachers and researchers. They became more active and reflective participants in their own classrooms and schools. They also developed more nuanced views of their students' interests and needs, moved away from deficit thinking, reported implementing new instructional strategies, and/or became stronger advocates for expanding students' learning opportunities.

Connected to their growth in agency as teachers, a second strength of the teacher research process was that most teacher participants deepened their understanding of their students. They learned to better attend to the complexities of their students' lives and to fashion more effective instructional supports to promote academic success. For example, Brent and Trisha shifted from thinking that their students were unmotivated to complete homework and uninterested in academic achievement due to cultural reasons, to realizing that students and their parents indeed cared about succeeding in school. As a result, they changed their research focus from trying to determine why their students failed to complete their homework, to implementing more effective instructional strategies to help students achieve in learning science.

Getting Equity into the Research Questions

Our careful examination of the evolution of teachers' research across the three stages of initial wonderings, formal research, and next steps yielded two unexpected findings related to equity. One, as part of their formal research stage, only two teacher researchers explicitly included equity in their formal research *questions*, even though six of the seven investigated two to three strands of equity in their

formal research *process*. Desiree, for example, raised the concern for limited access to cognitively demanding mathematics in her initial wonderings, but eliminated mention of access in her formal questions. Despite this absence, her research on making mathematics word problems more understandable and relevant to her students, particularly her underserved students, did have a clear equity component. A second unexpected finding looking across the three research stages was that once teachers identified an equity concern to help inform their research, they did not necessarily maintain a focus on equity. In the cases of both Suzie and Michelle, attention to equity in an earlier stage of their teacher research project did not guarantee that a concern for equity would persist throughout.

We argue that these two findings should serve as a caution to scholars who study teacher researchers. Although research questions can suggest what is examined in a given study, they do not necessarily provide a complete picture of the intents and interests in conducting inquiry (Salerno & Kibler, 2015). In our study, had we examined only the evolution of questions across stages, rather than include the research process as well, we would have concluded that many teacher participants grew resistant to investigating equity over time. Further, because attention to equity can shift, particularly when the research process is iterative, researchers must trace a teacher researcher's entire trajectory, not simply examine one point in time.

We also argue that these two findings should serve as food for thought for professional developers engaged in equity work. Professional developers should carefully consider how much time and energy they devote to working with teacher researchers in crafting initial research questions versus posing critical questions about the kinds of data collected and the ways those data are analyzed; the latter opportunities might be more important when attempting to investigate equity concerns in classrooms. Further, once equity has been included in an investigation, professional developers must ensure that attention to equity does not wane over time. Here, we suggest that identifying a collective research focus cemented by a common definition of equity might help. We explore this further below.

The Benefits and Costs of Encouraging "One's Own" Research into Equity

In TEMSE, teacher researchers were expected to develop their own definitions of equity and to devise their own research questions, so as to be responsive to their unique classroom, school, and community contexts. In our analysis of data, we identified two consequences of this decision to forgo a common equity definition. One consequence was positive. As professional developers expected, because each teacher participant was asked to develop and investigate a definition of equity relevant to her or his particular instructional context, most were able to generate powerful insights into the teaching and learning process. For example, Suzie began her formal research process convinced that her investigation of a new organizational system did not include an equity component. However, by examining students' performance by gender, ethnicity, first language, and free or reduced price lunch, she learned that some student groups benefited more from the changes she made to her practice than others. As such, Suzie's understanding of her students and their different instructional needs deepened as a result.

A second consequence of allowing teachers to craft their own equity definitions and research projects was negative. Because teachers were given the freedom to select their own topic of investigation, they did not necessarily choose to explore issues or enact strategies that the educational research community might consider to be at the forefront of equity pedagogy. Suzie's focus on the organization of students' notebooks is a case in point. As a second example, Michelle tried out several different reform-based instructional strategies, but quickly abandoned that work to return to exploring the construct of learned helplessness. With a common definition of equity and a collective research project, all teacher researchers might have researched topics better aligned with equity scholarship and made further strides in their efforts at transformation.

The Importance of Sustained Engagement

Our final implication speaks to sustained engagement. From our examination of changes in teachers' views and reported practices, we found that most teachers experienced substantive growth in their understanding of equity issues, while one, Michelle, maintained her initial views. We also found that teachers experienced more growth in their understanding of teachers and students, than of families and communities. How do we account for these differences?

One factor that emerged as important in promoting teacher growth through engagement in teacher research was sustained examination of students in relation to instructional practices. We argue that teachers' movement toward equity in relation to themselves and their students resulted from careful and thorough consideration of how the data they collected could inform their subsequent actions. Brent and Trisha, for example, used students' responses provided from initial surveys and focus group interviews to change their research focus from homework to how they structured and delivered classroom lessons. They then continued to regularly solicit feedback from students and to modify their instruction accordingly. Michelle, in contrast, began with a focus on learned helplessness, briefly moved to investigating different instructional strategies, and then returned to her initial interest. As such, we argue that because all teacher participants except for Michelle sustained their focus on a particular aspect of the teaching and learning process, they were able to deepen their understanding of teachers and students in relation to equity. Further, because all teacher participants gave only marginal attention to learning about students' out-of-school lives, their views and reported practices related to families and communities changed less than those related to teachers and students.

Professional developers, then, should ask teachers to continue to reflect, build on, and react to what they learn from their research over time rather than facilitate quick movement across studies. They must remain confident that most initial research questions—even those that are narrowly framed and/or that lack an equity focus—can lead to insights and informed action related to equity if multiple cycles of examining instruction in light of student learning is pursued thoughtfully and thoroughly. In addition, if change in teachers' views of families and communities is a priority, teachers must be provided explicit and adequate time and space to pursue research that is directly related to students' out-of-school lives.

Concluding Remarks

In sum, teacher research appears a fruitful professional learning strategy to use with practicing science and mathematics teachers interested in better understanding and addressing issues of equity and diversity in their classrooms. As with all professional development strategies, however, we found teachers' engagement in research to have weaknesses as well as strengths. We close with ways to possibly improve equity professional development opportunities and the research conducted on such efforts that emerge from consideration of the limitations of our current study, limitations that resurface the importance of teacher agency (Anderson, 2010) in teaching toward equity introduced in our conceptual framework above.

One limitation of our study was the gradual withdrawal of five of our 12 initial teacher participants. This disrupted our school team model: Suzie became the only teacher from Prairie High School. However, because all teacher participants except for Brent and Trisha conducted individual research projects, Suzie's status as the lone teacher from Prairie may not have had much impact on how her investigation into and ideas about equity changed over time. Further, because this study identified both strengths and limitations in allowing teachers to select their own topics of inquiry, it is not clear whether Suzie would have learned more from her research project if her colleagues had continued their involvement in TEMSE. More research is needed, then, to determine both (a) whether being a member of a school team is needed for impactful teacher research and/or (b) whether a common research agenda is more effective than context-specific, independent investigations in promoting teacher change. In other words, more research is needed to understand the strengths, limitations, and points of intersection between teacher agency and teacher–teacher collaboration in the context of equity professional development efforts.

As a second limitation, we did not follow teacher researchers after TEMSE ended to ensure changes in views and reported practices were sustained over time. One might expect teachers to retain or expand their understanding of equity, given the importance placed on teacher agency and ownership in the TEMSE professional development effort. Future studies could explore whether developing an individual definition of equity and participating in independent teacher research, both of which could be construed to enhance teacher ownership of the change process, leads to change sustained over time.

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