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School Resources in Teaching Science to Diverse Student Groups: An Intervention's Effect on Elementary Teachers' Perceptions

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Abstract Elementary school teachers' perceptions of school resources (i.e., material, human, and social) for teaching science to diverse student groups were examined across three school districts from one state. As part of a 3-year curricular and professional development intervention, we examined the effect on teachers' perceptions after their first year of participation. The study involved 103 fifth-grade teachers from 33 schools participating in the intervention and 116 teachers from 33 control schools. The teachers completed a survey at the beginning and end of the school year. As a result of the intervention, teachers in the treatment group reported more positive perceptions of school resources than teachers in the control group.

Keywords School resources · Teacher professional development · English learners · Student diversity

Introduction

In a school setting, resources are critical for teaching and learning. Three categories of school resources are essential: material, human, and social (Gamoran, Secada, & Marrett, 2006; Spillane & Thompson, 1997). Demands for resources are greater in urban schools, which tend to be under-resourced. In particular, urban schools have to consider how to divert a portion of already limited resources to

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science instruction after the bulk of resources are taken up by language arts and mathematics instruction (Knapp & Plecki, 2001; Smith, Nelson, Trygstad, & Banilower, 2013; Spillane, Diamond, Walker, Halverson, & Jita, 2001). In addition, urban schools tend to have high proportions of non-dominant student groups who lag behind their dominant peers in science achievement. Thus, science education reform must ensure that all students receive equitable resources to learn science and science teachers have professional development opportunities in teaching science with diverse student groups.

In this study, we address teachers' perceptions of school resources (material, human, and social) for teaching science to diverse student groups. The study took place during the first-year implementation of a 3-year scale-up intervention aimed at improving elementary teachers' knowledge and practices in teaching science to diverse student groups in the context of high-stakes science assessment and accountability policy. Using a cluster randomized controlled trial, the study involved all fifth-grade science teachers from 33 treatment schools participating in the intervention and 33 control schools across three school districts in one state. The study examined the intervention's effect on teachers' perceptions of school resources after their first year of participation. The first-year results provide the basis for the longitudinal results of teachers' perceptions of material, human, and social resources after completion of the 3-year period of the intervention (described in more detail in "Implications" section later).

Literature Review

The literature identifies three categories of organizational resources: material, human, and social (Gamoran et al., 2006; Spillane & Thompson, 1997). In schools, material resources include equipment (e.g., curriculum, computer technology, science supplies), time (e.g., time available for teaching, time for professional development, time for collaboration among teachers), and funding (e.g., expenditures for school personnel and other purposes related to teaching and learning). Human resources, or human capital, include the knowledge, skills, and dispositions that individuals (e.g., teachers) need to effectively teach a broad range of students. Social resources, or social capital, as laid out in Coleman's (1988) landmark study of the foundations of social theory, are concerned with the relations among individuals (e.g., teachers, principals, and parents) in a school, including such norms as trust, collaboration, common values, shared responsibility, sense of obligation, and collective decision-making. In the literature, the terms human resources and human capital are used interchangeably, as are the terms social resources and social capital. In this study, the terms material resources, human resources, and social resources are used. The following bodies of literature informed this study: (a) organizational resources for science instruction with diverse student groups and (b) the role of teacher professional development in generating school resources.

Organizational Resources for Science Instruction with Diverse Student Groups

School resources are critical for science instruction, especially for elementary science instruction. Science often receives less instructional time (a form of material resources) than language arts and mathematics. Over the past two decades, instructional time for science in elementary schools declined, whereas instructional time for language arts and mathematics increased (Blank, 2013). In addition, science teaching and learning requires access to equipment to engage in hands-on, inquiry-based science (Smith et al., 2013).

Most elementary teachers are unprepared to teach science effectively in terms of content knowledge and teaching practices, forms of human resources (Smith et al., 2013). Additionally, most teachers are unprepared to address student diversity, another form of human resources (Banilower et al., 2013). This includes both general practices, such as how to strive for cultural congruence with diverse student groups, and content-specific practices, such as how to structure inquiry-based science with English language learners or ELLs (Bunch, 2013).

Because teaching for inquiry and understanding with diverse student groups requires new kinds of equipment, new types of teachers' knowledge and practices, and new relationships among teachers or with administrators, the impact of professional development depends in part on the availability of these resources for implementation. Teachers who are not interested in participation in such professional development sometimes resist, if not work directly against, programmatic changes that are supported by other teachers in their school, thereby revealing organizational divides within the school (i.e., lack of social resources; Bryk & Schneider, 2002; Gamoran et al., 2003, 2006).

Principal support for change in teaching practices and student learning is critical to promote teachers' knowledge and skills (human resources) and to build shared goals, collaboration, and trust among teachers in a school (social resources; Banilower, Heck, & Weiss, 2007; Roehrig, Kruse, & Kern, 2007; Supovitz & Turner, 2000). Principal support for professional development is particularly important for whole-school initiatives in urban settings (Johnson, 2006, 2007).

Parents play a role as a resource for teaching and learning. In studying the Chicago School Reform Act of 1998, Bryk and Schneider (2002) examined relational trust, specifically teacher–parent trust as well as teacher–teacher trust and teacher–principal trust (social resources). Teachers were asked to assess whether they felt mutual respect in their relationships with parents. The results indicated that teachers' perceptions of parental support were related to school performance on the annual standardized tests in reading and mathematics.

Organizational resources are likely to have a greater impact on the learning opportunities of non-dominant students compared to their dominant peers (Gamoran et al., 2003; Smith et al., 2013; Spillane et al., 2001). This is because dominant students (i.e., White, middle- or upper-class, and native speakers of standard English) are more likely to access other supports for their learning, such as better equipped schools, more material resources at home, and highly educated parents. In contrast, the academic success of non-dominant students (i.e., students of color, students from low-income families, and students learning English as an additional language) depends more heavily on the quality of their school environment, and yet, they are less likely to have access to high-quality schools. Students and teachers in urban schools often face challenges, including a generalized lack of material resources in terms of equipment, time, and funding to teach science (Hewson, Kahle, Scantlebury, & Davies, 2001; Knapp & Plecki, 2001; Smith et al., 2013; Spillane et al., 2001). Yet, hands-on, inquiry-based science is particularly effective with ELLs and students with limited formal science experience (Lee, 2005; Rosebery & Warren, 2008). In addition, the neediest students in urban or low-performing schools often have the least prepared teachers who are frequently teaching out of their subject areas or without teacher certification (Tuerk, 2005). Not all teachers are equally effective with different student groups. Loeb, Soland, and Fox (2014) found that while teachers who were effective with non-ELLs were also effective with ELLs, teachers who spoke the home language of ELLs or possessed bilingual certification tended to produce relatively greater gains for ELLs than for non-ELLs. In school-wide initiatives, conflicts or mistrust among teachers or with administrators are often more acute in urban schools than suburban schools, due to limited resources as well as prospects of severe sanctions for poor performance according to accountability measures (Bryk & Schneider, 2002; Gamoran et al., 2003; Spillane & Thompson, 1997). Thus, inequitable resources for non-dominant students are a central concern.

Research on school resources is typically conducted as qualitative case studies with small numbers of schools (Lampert, Boerst, & Graziani, 2011; Penuel, Riel, Krause, & Frank, 2009; Rivera Maulucci, 2010). For example, Rivera Maulucci (2010) examined how middle school science teachers activated resources for science teaching in one high-poverty, low-performing urban school. The results of critical narrative inquiry suggested that science education was marginalized by school-level constraints, namely the lack of material, cultural, social, and symbolic resources. Material resources included lab tables, sinks, consumable supplies, non-consumable equipment, and textbooks. Cultural resources included teachers' knowledge, skills, education, and contextual experience. Social resources included trust, solidarity, and relationships among teachers as part of social networks. A symbolic resource arose when a cultural value was ascribed to teaching efforts, such as when science education was prioritized in a school curriculum. Constraints of these school-level resources paved the way for privileging literacy and mathematics over science education. To resist marginalization, teachers activated resources by collaborating with a lab coach, teaming with each other to gain a support network, and making time for science despite administrative pressure to spend instructional time on literacy and mathematics.

Lee, Maerten-Rivera, Buxton, Penfield, and Secada (2009) administered a survey to a large number of urban elementary school teachers to examine their perceptions of resources in teaching science with diverse student groups including ELLs. The study involved 221 third-, fourth-, and fifth-grade teachers from 15 urban elementary schools in a large urban school district. The teachers reported that while they taught science to promote students' inquiry and understanding in most lessons, they used English language development strategies or home language with

ELLs only in some lessons (i.e., human resources). They identified supports (e.g., teacher collaboration and principal support as social resources) and barriers (e.g., shortage of science supplies and large class size as material resources) in teaching science with diverse student groups. They also reported rarely discussing student diversity (e.g., ELLs, culturally diverse students, students with disabilities) with other teachers at their schools (i.e., social resources). The teachers' lack of attention to student diversity was a particular concern, considering that the majority of both the teachers themselves and their students were from non-dominant backgrounds.

The Role of Professional Development in Generating School Resources

Professional development opportunities generated through external relations (e.g., experts from local universities serving as sources of knowledge; external institutions and organizations providing financial resources) play an important role in education reform (Coburn & Russell, 2008; Gamoran et al., 2003; King, 2002; Parise & Spillane, 2010). These relations provide time for professional development and/or access to equipment or money (i.e., material resources) that promote change in teaching practices and student learning. These relations also develop teachers' knowledge, skills, and dispositions (i.e., human resources). In addition, external relations build shared understandings and collaboration to achieve a common, school-wide goal (i.e., social resources). Although external resources and expertise can be an important source of stimulation, the more important point is that through the process, schools "grow" their own internal resources as teachers increase their knowledge and build trust and collaboration.

Studies have addressed how professional development through external relations generated resources to change science teaching practices and student learning. These studies typically involved qualitative case studies with small numbers of schools (Coburn & Russell, 2008; Gamoran et al., 2003; King, 2002). Gamoran et al. (2003), for example, described "design collaboratives" in which teams of researchers collaborated with teachers and administrators at six elementary, middle, and high schools to design classroom environments in order to support student learning with understanding in mathematics and science. Successful efforts entailed the strategic use of material, human, and social resources to capitalize on teachers who could offer leadership roles and to help teachers who would otherwise resist change. In three schools serving non-dominant student groups, there was more competition for resources that were also needed to support other subjects, in addition to mathematics and science. This often resulted in educational practices that were inequitable for non-dominant students.

Parise and Spillane (2010) used a survey with a large number of teachers to examine the relationship between teachers' learning opportunities and changes in their instructional practices, as well as schools' organizational conditions that might affect changes, in language arts and mathematics. The data came from an evaluation of a leadership professional development program involving 714 respondents in 2005 and 704 respondents in 2007 from all of the 30 elementary schools in a mid-sized urban school district. Results indicated that teachers' reports of learning opportunities through both formal professional development (e.g., number of professional development sessions, number of undergraduate or graduate courses in English or mathematics) and on-the-job opportunities to learn (e.g., collaborative discussion, peer observation, feedback) were significantly related to reported changes in instructional practices. However, teachers' perceptions of schools' organizational conditions, including professional learning community (e.g., teacher trust, collective responsibility) and principals' communication of instructional goals with teachers, were not significantly related to their reported changes in instructional practices.

Purpose of the Study

This study is part of a 3-year large-scale curricular and professional development intervention (described in the next section). The intervention involved all fifth-grade science teachers from 33 treatment schools participating in the intervention and 33 control schools across three school districts in one state. Using a randomized controlled trial design, this large-scale study examined the following research question:

> What was the effect of the intervention on teachers' perceptions of school resources (material, human, and social) in teaching science to diverse student groups after the first year of implementation?

Data for this large-scale study consisted of teachers' responses to a survey addressing their perceptions of material resources (equipment and time); human resources (teaching practices to promote science learning and language development); and social resources (teacher collaboration, administrator support, and parent/family support). Similar to the approach taken by Parise and Spillane (2010), the human resources scales in the survey focused on behavioral aspects of teaching practices (e.g., frequencies of specific practices). According to Desimone (2009), surveys can provide "valid and reliable data on the amount of time that teachers spend on specific practices occurring during a set time period—up to a year" (p. 190). The material and social resources scales focused on teachers' perceptions (e.g., equipment or time as a barrier; feelings about colleagues, administrators, and parents). Examining teachers' perceptions is important because studies using surveys with large numbers of teachers found that teachers' perceptions of resources were related to teaching practices and student achievement outcomes (Bryk & Schneider, 2002; Supovitz, Sirinides, & May, 2010). In addition, Bryk and Schneider (2002) found that "the survey reports are quite consistent with our field observations" (p. 97).

Teacher Professional Development Intervention

Below we describe the intervention in terms of material, human, and social resources.

Material Resources

Material resources included curriculum, time for science instruction, and time for teacher workshops.

Curriculum

A comprehensive, stand-alone, year-long science curriculum for fifth grade was developed based on our previous research (Lee et al., 2009) and further refined for this intervention. Teachers were provided with complete class sets of curriculum, including consumable student workbooks, teachers' guide, science supplies, and supplements on the project website. While the 33 treatment schools implemented the project-developed intervention curriculum, the 33 control schools implemented the district-adopted textbook series as "business as usual."

Time for Science Instruction

At the end of the school year, treatment and control teachers reported how much time they spent teaching science throughout the school year. Science was taught regularly and extensively, which reflects the fact that high-stakes science assessment counted toward school accountability in fifth grade: 58% of the teachers reported teaching science for 150–300 min per week (indicating on average 30 min–1 h every day), and 16% reported teaching science more than 300 min per week (indicating on average more than 1 h every day). Both the total minutes of science instruction per week and the average length of science class were comparable between the treatment and control groups.

Time for Teacher Workshops

At the end of the school year, teachers reported time for professional development in science and ESOL during the school year. The teachers in the treatment group were asked to exclude the five full-day workshops that were part of the intervention. In the teacher sample, 37% of control teachers and 47% of treatment teachers reported that they did not attend any science workshops during the year. In addition, 72% of control teachers reported that they did not attend any ESOL workshops, compared to 55% of treatment teachers. In general, professional development opportunities in teaching science and working with ELLs were limited for the teachers in the study (aside from the five full-day workshops as part of the intervention for the treatment group).

Human Resources

Human resources were provided to improve teachers' science knowledge and instructional practices through curriculum and teacher workshops in three areas: (a) state science standards, (b) science inquiry and understanding, and (c) science instruction with diverse student groups with a focus on ELLs.

State Science Standards

Special consideration was given to ensure alignment between the curriculum and the state science standards. Each chapter in the student workbooks begins with a list of the science standards and benchmarks addressed. Furthermore, each hands-on inquiry activity, reading passage, and writing section identified the science standard(s) and benchmark(s) addressed. In particular, the intervention helped teachers recognize how science inquiry was related to the state science standards and, thus, could enhance performance on the state science assessment.

Science Inquiry and Understanding

The intervention was grounded in reform-oriented practices to promote students' science inquiry and understanding (National Research Council, 2000, 2007). Science education reform highlights that students engage in science inquiry related to the practice of science. Students should also develop deep and complex understanding of science concepts, make connections among concepts, and apply concepts in explaining natural phenomena or real-world situations. To promote students' science inquiry and understanding, teachers need to know the subject matter they teach (Heller, Daeler, Wong, Shinohara, & Miratrix, 2012; Kennedy, 1998). For science inquiry activities, the teachers' guide provided science background information and explanations for the questions under investigation and related natural phenomena.

Science Instruction with ELLs

The intervention highlighted the following five areas where science and literacy are integrated, which can benefit all students but ELLs in particular (Fathman & Crowther, 2006; Janzen, 2008; Lee & Buxton, 2013; Rosebery & Warren, 2008). First, effective teachers highlight various strategies for developing content area literacy, including activation of prior knowledge, engagement with expository science texts, and use of graphic organizers. Second, effective teachers utilize second language pedagogies (ESOL strategies) and strategies typical of contextualized experiential approaches, including hands-on activities, realia, purposeful activities, and multiple examples of language in use. Third, effective teachers facilitate ELLs' participation in classroom discourse to enhance students' understanding of academic content. They are sensitive to the varying levels of students' developing language proficiency, adjust the level and mode of communication, and use multiple modes of representation (gestural, oral, pictorial, graphic, and textual). Fourth, effective teachers focus on students' home language as an instructional support. They use science terms in students' home language, highlight cognates between English and the home language, allow code-switching, and encourage bilingual students to assist less English proficient students in their home language. Finally, effective teachers elicit students' "funds of knowledge" from home and community contexts related to science topics (González, Moll, & Amanti, 2005) and use students' cultural artifacts and community resources in ways that are both academically meaningful and culturally relevant (Solano-Flores & Nelson-Barber, 2001).

Social Resources

Social resources were addressed by encouraging collaboration among all fifth grade science teachers from the participating schools within each school and each school district. Throughout the workshops, treatment teachers were actively involved as they shared questions, suggestions, and examples of their own practices and beliefs. At the end of each workshop, teachers from each school were given time for collaborative planning. As such, collective participation of all fifth-grade science teachers from the same schools in each district provided the context for the intervention.

Methods

Research Setting

The study was implemented in three school districts in a southeastern state. According to the National Center for Education Statistics (NCES) (2006), District A, located in the northeastern part of the state, was designated as urban. District B, located in the southwestern part of the state, was designated as urban/suburban. District C, located in the central part of the state, was also designated as urban/suburban. The three districts encompassed a wide range of racial, ethnic, socioeconomic, and linguistic diversity. During the 2012–2013 school year, District A was 45% Black, 8% Hispanic, 40% White non-Hispanic; 52% received free or reduced price lunch (FRL); and 3% were ELLs. District B was 28% Black, 15% Hispanic, 51% White non-Hispanic, 52% FRL, and 8% ELLs. District C was 30% Black, 34% Hispanic, 28% White non-Hispanic, 60% FRL, and 14% ELLs.

Research Design

During the 2012–2013 school year, District A had 103 elementary schools, District B had 44 elementary schools, and District C had 125 elementary schools. A cluster randomized control trial was conducted. Within each of the three school districts, 22 elementary schools were randomly selected to participate in the study, yielding a total of 66 schools. Within each district, half of the selected schools were randomly assigned to the treatment group and half to the control group, yielding a total of 33 treatment schools and 33 control schools across the three districts.

Participants

All fifth-grade science teachers in the 66 schools participated in the study. During the 2012–2013 school year, the project involved 123 teachers in the treatment group and 135 teachers in the control group. Among the 258 teachers, 30 were in their first year of teaching science. Since the pre-survey at the beginning of the school year asked teachers to report on their science teaching practices during the prior year, there were no baseline data available for these 30 teachers; thus, they were not included in the analyses. Among the remaining 228 teachers, three did not complete the survey at the beginning of the school year, and six did not complete the survey at the end of the school year because they were no longer working at the schools. The final sample consisted of 219 teachers, including 103 in the treatment group and 116 in the control group. The number of teachers per school ranged from 1 to 10, with an average of three teachers per school.

In terms of teacher demographic and professional background, the majority of the teachers in the sample were female, White, non-Hispanic, and native speakers of

Table 1 Comparison of treatment and control teacher background variables (dichotomous and categorical variables)

Variable	Control ($n = 116$) (%)	Treatment ($n = 103$) (%)
Demographic background		
Gender		
Female	85	80
Male	15	20
Ethnicity		
White, non-Hispanic	74	76
Black, non-Hispanic	13	12
Hispanic or Latino	12	10
Asian	1	2
Native language[a]		
English	96	98
Spanish	8	8
Other fluent language[a]		
English	4	2
Spanish	2	5
Professional background		
Highest degree		
Bachelor's degree	61	65
Master's degree or higher	39	35
ESOL training[a]		
Met ESOL requirement through college coursework	22	26
Met ESOL requirement through school district (META)	64	57
Completed bachelor's or master's degree in ESOL	6	7
Other	9	16
None	4	1

[a] Teachers could select more than one response

English (see Table 1). Most of the teachers had a bachelor's degree (63%) and met the state's ELL requirement via endorsement through the school district (61%). As shown in Table 2, there were no differences between teachers in the treatment group and the control group in terms of years of teaching, years of teaching science, number of science courses taken, or number of science methods courses taken.

Instrument

We developed a survey to assess teachers' perceptions of school resources (see "Appendix" section). The survey consisted of ten scales composed of 3–7 items each. The two scales addressing material resources were compiled from existing instruments [National Survey of Science and Mathematics Education as cited in Weiss, Banilower, McMahon, and Smith (2001) and Banilower et al. (2013)]. The four scales addressing human resources were a refined version of scales used in our previous research (see Lee et al., 2009, 2016; Lee & Maerten-Rivera, 2012 for details), and the four scales addressing social resources were developed based on relevant literature (Bryk & Schneider, 2002; Gamoran et al., 2003). All of the items were reviewed by two experts in the field of science education and revised based on their feedback.

In terms of *material resources*, the survey included the following two scales: (a) a scale on equipment as a school-level barrier (shortage of science supplies, shortage of computers and technology, and shortage of classroom facility for science labs) and (b) a scale on time as a school-level barrier (lack of time for science instruction, lack of time for teachers planning together, and lack of time for teacher professional development). The ratings included 1 (not a barrier), 2 (minor barrier), 3 (moderate barrier), and 4 (major barrier).

Scales for *human resources* included the following: (a) teaching practices to promote students' scientific understanding, (b) teaching practices to promote students' science inquiry, (c) language development strategies, and (d) home language use with ELLs. To measure the teachers' reported practices, the items used a four-point rating system ranging from 1 (never or almost never) to 4 (every lesson).

Scales for *social resources* included the following: (a) teacher collaboration in science practices, (b) teacher collaboration in science tasks, (c) school

Table 2 Comparison of treatment and control teacher background variables (continuous variables)

Variable	Control (n = 116)		Treatment (n = 103)		Overall (n = 219)		Diff.	t	p
	M	SD	M	SD	M	SD			
Professional background									
Years of teaching	13.2	9.23	12.1	9.1	12.7	9.1	1.1	0.85	0.40
Years of teaching science	10.9	7.81	9.7	6.5	10.3	7.2	1.2	1.29	0.20
Science courses	2.6	2.61	3.2	3.1	2.9	2.9	−0.7	−1.67	0.10
Science methods courses	1.6	1.66	1.5	1.1	1.5	1.4	0.1	0.35	0.72

administration support of science, and (d) parent and family. Scales (a) and (c) were measured using a four-point rating system ranging from 1 (strongly disagree) to 4 (strongly agree). Scale (b) was measured using a five-point rating system (0 = never; 1 = 1 time; 2 = 2 or 3 times; 3 = 4–8 times; 4 = more than nine times during a typical month for at least 15 min). Scale (d) was measured using a four-point rating system (1 = not a barrier; 2 = minor barrier; 3 = moderate barrier; 4 = major barrier).

Data Collection and Analysis

In the treatment group, the teacher survey was administered prior to the start of the intervention (pre) during the first teacher workshop and again at the completion of the first year of the intervention (post) during the final workshop of the school year. In the control group, the survey was administered at either district buildings or school sites at the beginning of the school year (pre) and at the end of the year (post).

As mentioned earlier, each scale in the survey had 3–7 items. The score for each scale was computed by averaging the responses to the items that composed the scale. The number of teachers responding to each item varied. For example, teachers with no ELLs in their classrooms did not respond to the items about the use of students' home language in their science instruction. A scale score was computed only for those respondents who had valid responses for at least 75% of the items in the scale. If someone answered fewer than 75% of a scale's items, the respondent's scale score was set to be missing and omitted from analyses. The reliability of the obtained scale scores was estimated using Cronbach's α. Internal reliability estimates for all of the scales were above an acceptable range of 0.70 (see Table 3).

Multilevel modeling (also known as hierarchical linear models; Raudenbush & Bryk, 2002) was used to examine the impact of the intervention on teachers' perceptions for each of the ten scales in the survey. Multilevel modeling takes into account the nested structure of the data. The data had a two-level structure whereby teachers (level 1) were nested in schools (level 2). Therefore, two-level models were used with two dummy coded variables for district included at level 2. To describe these models, we denote the score on the teacher post-survey scale score for the ith teacher of the kth school by POST_{ik}. The general form of the multilevel model is given by the following:

$$\text{Level-1 model: } \mathrm{POST}_{ik} = \pi_{0k} + \pi_1(\mathrm{PRE}_{ik}) + e_{ik}$$
$$\text{Level-2 model: } \pi_{0k} = \gamma_{00} + \gamma_{01}(\mathrm{TRT}_k) + \gamma_{02}(\mathrm{Dist1}_k) + \gamma_{03}(\mathrm{Dist2}_k) + \gamma_{04}(\mathrm{Pre}_k) + r_{0k}$$

where PRE_{ik} corresponds to the teacher pre-survey scale score centered at the school's mean, TRT_k corresponds to school condition (treatment vs. control), $\mathrm{Dist1}_k$ and $\mathrm{Dist2}_k$ correspond to two dummy coded variables representing district, Pre_k corresponds to the pre-survey school mean centered at the district mean, and errors are denoted by e_{ik} and r_{0k}. The overall treatment effect is represented by the coefficient γ_{001}. Separate multilevel models were estimated for each scale score.

Table 3 Descriptive statistics for school resources scales

Scale	ICC	Time	α	Control			Treatment			*t*	*p*
				n	M	SD	*n*	M	SD		
Material resources											
Equipment	0.39	Pre	0.73	114	2.26	0.90	97	2.47	1.07	1.54	0.126
		Post	0.80	114	2.23	0.92	103	2.07	0.89		
Time	0.11	Pre	0.85	114	2.59	0.83	97	2.60	0.77	0.07	0.947
		Post	0.83	116	2.70	0.93	102	2.43	0.80		
Human resources											
Teaching practices for understanding	0.13	Pre	0.79	110	2.81	0.48	98	2.79	0.54	−0.10	0.924
		Post	0.75	116	2.87	0.44	102	3.10	0.44		
Teaching practices for inquiry	0.09	Pre	0.79	111	2.28	0.46	97	2.34	0.49	0.94	0.346
		Post	0.81	115	2.45	0.44	100	2.67	0.50		
Language development strategy	0.10	Pre	0.76	105	2.83	0.48	96	2.88	0.53	0.59	0.553
		Post	0.73	115	2.93	0.45	100	3.19	0.45		
Home language use	0.13	Pre	0.84	72	1.62	0.68	73	1.97	0.84	2.83	0.005*
		Post	0.83	70	1.79	0.75	65	2.30	0.98		
Social resources											
Teacher collaboration in science practices	0.20	Pre	0.78	104	2.70	0.56	87	2.80	0.59	1.27	0.207
		Post	0.80	115	2.57	0.61	98	2.75	0.66		
Teacher collaboration in science tasks	0.19	Pre	0.87	105	3.04	0.92	86	3.16	0.99	0.78	0.434
		Post	0.89	116	3.26	1.02	103	3.27	1.00		
School administration support of science	0.26	Pre	0.85	102	2.88	0.54	88	2.88	0.57	0.04	0.968
		Post	0.87	115	2.79	0.56	98	2.85	0.67		
Parent and family	0.34	Pre	0.84	104	2.51	0.80	87	2.84	0.88	2.70	0.008*
		Post	0.81	114	2.51	0.86	103	2.42	0.88		

We applied the Benjamini–Hochberg correction to adjust the *p* value in the *t* test analyses

* $p < .01$

Because we tested ten related outcomes, we applied the Benjamini–Hochberg correction method for adjusting *p* values of the main treatment effect (Benjamini & Hochberg, 1995).[1] For each scale, we also calculated an effect size by dividing the unstandardized regression coefficient for the treatment effect (i.e., an estimate of the

[1] The What Works Clearinghouse adopted the Benjamini–Hochberg method (Benjamini & Hochberg, 1995) to correct for multiple comparisons. The traditional approach for adjusting for multiple comparisons, the Bonferroni method, was shown to be unnecessarily stringent for many practical situations. To apply the Benjamini–Hochberg method, we followed the steps outlined in the What Works Clearinghouse Procedures and Standards Handbook, Version 3.0, pp. G1–G5.

difference between treatment and control at posttest) by the pooled standard deviation of the posttest.

Results

Table 3 shows descriptive statistics of the survey at pre and post. The *t* test results comparing means on each scale between the treatment and control groups at pre are also presented.

As shown in Table 1, there were no significant differences between the treatment and control groups on eight of the ten scales at the start of the intervention. Specifically, there were no differences between the groups on the material resources scales (equipment and time as barriers for teaching science), three of the human resources scales (teaching practices for understanding, teaching practices for inquiry, and use of language development strategies), and three of the social resources scales (teacher collaboration in science practices, teacher collaboration in science tasks, and school administration support of science). Teachers in the treatment group, however, reported more use of home language (one of the human resources scales) and perceived parent and family (one of the social resources scales) as more of a barrier to their science teaching than teachers in the control group.

The results of the multilevel analyses indicated that there was a significant treatment effect of the intervention for seven of the ten scales (see Tables 4, 5, and 6). As shown in Table 4, there was a significant treatment effect on both material

Table 4 Treatment effect on material resources

Term	Equipment (as barrier)	Time (as barrier)
N		
School	63	63
Teacher	209	210
Fixed effects		
Intercept	0.58***	0.96**
Treatment	−0.31**	−0.27*
Pretest (school average)	0.24*	0.09
Pretest (teacher level)	0.47***	0.57***
District 1	0.24	0.17
District 2	0.01	−0.01
Random effects		
School	0.06	0.05
Teacher	0.37***	0.48***
Treatment effect size	−0.34	−0.30

The items on the equipment and time scales were worded as negatives

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 5 Treatment effect on human resources

Term	Teaching practices for understanding	Teaching practices for inquiry	Language development strategies	Home language use
N				
School	63	63	64	46
Teacher	211	210	206	111
Fixed effects				
Intercept	1.69***	1.37***	1.71***	1.17***
Treatment	0.23***	0.19**	0.25***	0.45*
Pretest (school average)	0.03	0.18	0.15	0.08
Pretest (teacher level)	0.39***	0.28**	0.28**	0.26*
District 1	0.00	0.04	−0.05	−0.02
District 2	0.02	0.04	0.05	0.21
Random effects				
School	0.01	0.00	0.00	0.05
Teacher	0.14***	0.18***	0.15***	0.60***
Treatment effect size	0.52	0.41	0.56	0.52

* $p < .05$; ** $p < .01$; *** $p < .001$

resources scales. As a result of the intervention, by the end of the school year, teachers in the treatment group perceived equipment as less of a barrier to teaching science than teachers in the control group ($p = .005$). Treatment teachers also perceived time as less of a barrier to teaching science ($p = .016$). The effect size was −0.34 for the equipment scale and −0.30 for the time scale.

As shown in Table 5, there was a significant treatment effect for all four human resources scales. Teachers in the treatment group reported using more teaching practices for understanding ($p < .001$), teaching practices for inquiry ($p = .002$), language development strategies ($p < .001$), and home language use ($p = .020$) than the control teachers. The magnitude of the effect on these four scales ranged from 0.41 to 0.56.

As shown in Table 6, there was a significant treatment effect for one of the four social resources scales. As a result of the intervention, teachers in the treatment group perceived parent and family as less of a barrier to their science teaching than did teachers in the control group ($p = .002$), even though at the beginning of the intervention it was the treatment teachers who perceived parent and family as more of a barrier. The magnitude of the effect was −0.41.

Discussion and Implications

We examined the effect of an intervention on elementary science teachers' perceptions of school resources (i.e., material, human, and social resources) for teaching science with diverse student groups after their first year of participation in

Table 6 Treatment effect on social resources

Term	Teacher collaboration in science practices	Teacher collaboration in science tasks	School administration support of science	Parent and family
N				
School	59	59	59	59
Teacher	190	192	192	189
Fixed effects				
Intercept	0.61*	1.40**	0.41	0.60**
Treatment	0.16	−0.03	0.05	−0.36**
Pretest (school average)	0.19	0.06	0.26	0.37**
Pretest (teacher level)	0.52***	0.55***	0.54***	0.43***
District 1	−0.03	−0.14	0.05	−0.22
District 2	0.08	0.06	0.19	−0.10
Random effects				
School	0.02	0.07	0.04	0.04
Teacher	0.26***	0.62***	0.22***	0.40***
Treatment effect size	0.25	−0.03	0.08	−0.41

The items on parent and family were worded as negatives

* $p < .05$; ** $p < .01$; *** $p < .001$

a 3-year intervention within the context of high-stakes science assessment and accountability policy.

Discussion

The results indicate that after 1 year, teachers who participated in the intervention had more positive perceptions of school resources than teachers in the control group on seven out of 10 scales. Several findings are noteworthy. First, teachers in the treatment group perceived materials as less of a barrier to teaching science than teachers in the control group. This finding suggests that teachers in the treatment group recognized the need for all the equipment (i.e., curriculum including student workbooks, teachers' guide, science supplies, and supplements on the project website) to carry out the inquiry activities in the curriculum throughout the school year. Furthermore, teachers in the treatment group perceived time as less of a barrier to their science teaching than teachers in the control group, even though both groups spent a comparable amount of time teaching science throughout the year (see Table 1). This finding suggests that the intervention might have ameliorated the treatment teachers' perception of the time constraint, despite the pressure to cover science standards for high-stakes science assessment and accountability.

Second, the treatment effect was greater on human resources than on material or social resources, as evidenced in the larger effect sizes. This finding supports the primary goal of the intervention focused on improving teachers' instructional practices. During the first year, the teacher workshops highlighted how to implement the curriculum to promote students' understanding and inquiry. The workshops also encouraged teachers to use language development strategies and home language in their science instruction.

Third, among the four social resources scales, the treatment effect was observed only on the parent and family scale: Treatment teachers perceived parent and family as less of a barrier at the end of the year. In contrast, there was no treatment effect on teachers' perceptions of teacher collaboration in science practices, teacher collaboration in science tasks, or school administration support of science. One possible explanation for the lack of impact on these scales might be that social resources such as collaboration among teachers and administrators may take a longer time to build than teachers' own instructional practices.

Finally, the lack of a significant effect for teacher collaboration in science practices (with an effect size of 0.25), in particular, is likely due to power issues. Power analyses conducted using Optimal Design (Raudenbush, Spybrook, Congdon, Liu, & Martinez, 2011) indicated that the study was sufficiently powered to detect effect sizes of 0.40.

Implications

This large-scale, experimental study makes important contributions to the literature on school resources. Research in this area mainly focused on case studies describing the utilization of school resources (Lampert et al., 2011; Rivera Maulucci, 2010; Penuel et al., 2009) or large-scale studies examining relationships between teachers' self-reports of school resources and teaching practices or student achievement outcomes (Bryk & Schneider, 2002; Parise & Spillane, 2010; Supovitz et al., 2010). This study adds to this literature by providing experimental evidence that a large-scale professional development intervention can be designed to have an impact on school resources. Specifically, the results of this study demonstrate that a professional development intervention can ameliorate teachers' perceptions of barriers (i.e., equipment, time, and parent and family) as well as enhance self-reported instructional practices. Also, the study was conducted in a state where science test scores at fifth grade counted toward school grades. This is important because at the grade level where science is tested, allocation of school resources to teach science can be particularly challenging given that the bulk of resources tend to be devoted to language arts and mathematics, especially in urban schools (Blank, 2013; Smith et al., 2013; Spillane et al., 2001).

The results of the study need to be interpreted in relation to its limitations. One limitation of the study is that it is based on teachers' self-reports. Even though teacher surveys can provide valid and reliable data about teaching practices (e.g., teaching practices to promote students' science inquiry, language development strategies), there is a concern that teachers may over-report reform-oriented practices, and thus, surveys can result in a too-optimistic view of the effect of an intervention (Desimone, 2009). Although observations could serve as a guard against over-reporting and provide a more objective measure, observations also have limitations, as they have to address observer biases, are "burdensome and expensive" (Desimone, 2009, p. 190), and are almost impossible in a large-scale intervention with a finite amount of funding.

Another limitation involves how teachers' perceptions of school resources (e.g., teachers' perceptions of science instructional time as a barrier, school administration support of science) compare to their actual utilization of such resources. This issue indicates a trade-off between large-scale studies that typically employ a survey of teachers' perceptions and qualitative case studies that typically employ field research. Although a mixed methods study using observations, surveys, interviews, or archives would be ideal (e.g., Bryk & Schneider, 2002), such study requires extensive resources for research expertise and expenses. Nonetheless, focusing on teachers' perceptions is important because they have been linked to teaching practices and student achievement outcomes (Bryk & Schneider, 2002; Parise & Spillane, 2010; Supovitz et al., 2010).

Finally, even though the study found a statistically significant impact of the intervention on seven of the 10 scales, determining whether the magnitude of the change is substantively important is difficult to establish. There are guidelines to help researchers meaningfully interpret effect sizes of different types of interventions on student outcomes (e.g., Hill, Bloom, Black, & Lipsey, 2008); however, no such guidelines exist for teacher outcomes (Jessaca Spybrook, personal communication, August 1, 2014). In our study, the effect sizes ranged from 0.30 to 0.56, which in practical terms meant that treatment teachers tended to move about a half a rating interval on the Likert scale from pre- to post-intervention. For example, a teacher who had reported using language development strategies during "some lessons" at the beginning of the year reported using these strategies between "some" and "most lessons" by the end of the year. To determine whether the magnitude of the change is of substantive importance, future analyses could examine whether these changes in teachers' perceptions are associated with student achievement outcomes.

The results of the study suggest areas for further research. In our ongoing research, additional time points will be used to extend this study as teachers continue their participation in the intervention over a 3-year period. In the current study, the first-year results are interpreted based on the constructs of school resources as they apply to student diversity in urban settings. Extending the first-year study, the further research involves review of the literature addressing long-term impacts of interventions and employment of longitudinal analysis addressing teacher attrition based on length of participation in the intervention (1, 2, or 3 years). Further research could also examine whether the treatment has differential effects on material, human, and social resources over the 3-year period of the intervention. In addition, further research could examine the relationship between change in teachers' perceptions of school resources and science achievement among diverse student groups. This research question involves linking teacher outcomes and student outcomes using mediational models of analysis.

The results of the intervention's effect during the first year offer insights for our ongoing intervention. While the first-year efforts focused on implementation of the curriculum, the ongoing efforts focus on enabling teachers to adapt the curriculum in meeting the needs of diverse student groups, including ELLs (human resources). At the same time, the intervention focuses on building collaboration through social networking among individual teachers, professional learning communities within and across schools, and support from administration at the district and school levels (social resources). As teachers strengthen human and social resources, our intervention could further enable the teachers to perceive equipment and time as less of barriers and, furthermore, to utilize equipment and time more effectively (material resources).

Finally, the results of the study offer insights for future efforts to design and investigate professional development interventions that capitalize on material, human, and social resources simultaneously (Coleman, 1988; Gamoran et al., 2003). Material resources in the form of equipment, time, or funding could be provided to teachers in order to implement reform-oriented practices in their classrooms. In turn, teachers' knowledge and skills could play a crucial role in guiding the constructive use of material resources. Furthermore, increased teachers' knowledge and practices could help to build trust and collaboration in achieving a common, school-wide goal. Through this process, schools and teachers "grow" their own internal resources to sustain the intervention after the external relations conclude (Coburn, Russell, Kaufman, & Stein, 2012).

Appendix: Teacher Survey Scales

I. Material Resources
Materials

1. Indicate how much of a **barrier** each of the following factors is to your **science teaching**.

	Not a barrier	Minor barrier	Moderate barrier	Major barrier
(a) Shortage of science resources (e.g., trade books, posters, and other supplements)	1	2	3	4
(b) Shortage of computers and technology for science instruction	1	2	3	4
(c) Classroom facility (e.g., lab set-up, insufficient space, furniture, etc.)	1	2	3	4

Time

2. Indicate how much of a **barrier** each of the following factors is to your **science teaching**.

	Not a barrier	Minor barrier	Moderate barrier	Major barrier
(d) Lack of time available to teach science	1	2	3	4
(e) Lack of time available for teachers to plan together	1	2	3	4
(f) Lack of time available for teacher professional development	1	2	3	4

II. Human Resources
Teaching Practices for Understanding

3. In your most recent teaching position, indicate how often **YOU** did the following in your **science lessons**.

	Never or almost never	Some lessons	Most lessons	Every lesson
(a) Use students' ideas to generate class discussion	1	2	3	4
(b) Connect science topics to one another	1	2	3	4

In your most recent teaching position, please indicate how often you **ASKED STUDENTS** to do the following in your **science lessons**.

	Never or almost never	Some lessons	Most lessons	Every lesson
(c) Explain the reasoning behind an idea	1	2	3	4
(d) Apply science concepts to explain natural events or real world situations	1	2	3	4
(e) Talk about things they do at home that are similar to what we do in science class (e.g., measurement, mixture, energy sources)	1	2	3	4
(f) Discuss their prior knowledge or experience related to the science topic or concept	1	2	3	4

Teaching Practices for Inquiry

4. In your most recent teaching position, please indicate how often you **ASKED STUDENTS** to do the following in your **science lessons**.

	Never or almost never	Some lessons	Most lessons	Every lesson
(a) Provide evidence (observations, data) to support claims	1	2	3	4
(b) Use measurement tools (e.g., ruler, thermometer, scale/balance, timer, graduated cylinder)	1	2	3	4
(c) Design investigations to test their own ideas	1	2	3	4
(d) Analyze data to identify patterns and relationships	1	2	3	4
(e) Write about what was observed and why it happened	1	2	3	4
(f) Use simulations or models to construct explanations	1	2	3	4

Language Development Strategies

5. In your most recent teaching position, please indicate how often **YOU** did the following in your **science lessons**.

	Never or almost never	Some lessons	Most lessons	Every lesson
(a) Present information in multiple graphic formats (e.g., graphs, charts, photos, diagrams, and models)	1	2	3	4
(b) Use realia (including hands-on activities) to help students develop academic language of science	1	2	3	4
(c) Adjust style of interaction based on varying levels of English proficiency	1	2	3	4
(d) Make science text comprehensible (e.g., underline important information, identify main ideas and details, make inferences)	1	2	3	4
(e) Make science talk understandable (e.g., clearer enunciation, longer wait time)	1	2	3	4
(f) Use science terms in various contexts (e.g., introduction, science investigation, writing, and discussion)	1	2	3	4
(g) Create small groups with varying levels of language proficiency to work together in science class	1	2	3	4

Home Language Use

If you have *NO* ESOL level 1–5 students in your science class(es), skip to question #7.

6. In your most recent teaching position, please indicate how often **YOU** did the following in your **science lessons**.

	Never or almost never	Some lessons	Most lessons	Every lesson
(a) Encourage more English proficient students to assist less English proficient students in their home language	1	2	3	4
(b) Allow students to discuss science using their home language	1	2	3	4
(c) Introduce key science vocabulary terms in both their home language and English	1	2	3	4
(d) Allow students to write about science ideas or experiments in their home language	1	2	3	4

III. Social Resources

Teacher Collaboration in Science Practices

7. We would like to know how you feel about teaching science **in your school**. Please indicate how strongly you agree or disagree with each statement.

	Strongly disagree	Disagree	Agree	Strongly agree
(a) Most teachers in this school have a shared vision of effective science instruction	1	2	3	4
(b) When I have questions about teaching science, I can get good advice from other teachers in this school	1	2	3	4
(c) I can rely on other teachers in this school to help me try out new teaching techniques in science	1	2	3	4
(d) Teachers plan for science instruction together	1	2	3	4

Teacher Collaboration in Science Tasks

8. Please indicate how often **YOU** did the following with other teachers **in your school** during a typical month **for at least 15 min**.

	Never	1 time	2–3 times	4–8 times	9+ times
(a) Share teaching materials and activities for science	0	1	2	3	4
(b) Share stories about teaching experiences in science	0	1	2	3	4
(c) Analyze a specific student's work in science	0	1	2	3	4
(d) Work together to develop activities for science instruction	0	1	2	3	4
(e) Share assessment tasks that reveal how students understand science	0	1	2	3	4

School Administration Support of Science

9. We would like to know how you feel about teaching science **in your school**. Please indicate how strongly you agree or disagree with each statement.

	Strongly disagree	Disagree	Agree	Strongly agree
(a) The school administration actively supports using the allocated time for science instruction	1	2	3	4
(b) The school administration allocates enough funding for supplementary science resources	1	2	3	4
(c) The school administration clearly communicates the importance of teaching science	1	2	3	4
(d) The school administration encourages faculty to plan for science instruction together	1	2	3	4
(e) The school administration recognizes student achievement in science	1	2	3	4
(f) The school administration demonstrates knowledge of Next Generation Sunshine State Standards (NGSSS) in Science	1	2	3	4

Parent and Family

10. Please indicate how much of a **barrier** each of the following factors is to **science learning in your school**.

	Not a barrier	Minor barrier	Moderate barrier	Major barrier
(a) Lack of participation in school activities (e.g., parent-teacher conferences, returning phone calls)	1	2	3	4
(b) Parent's (or guardian's) limited English proficiency	1	2	3	4
(c) Lack of supervision and support for homework	1	2	3	4

References

Banilower, E. R., Heck, D. J., & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the National Science Foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching, 44*, 375–395.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society Series B Methodological, 57*, 289–300.

Blank, R. K. (2013). Science instructional time is declining in elementary schools: What are the implications for student achievement and closing the gap? *Science Education, 97*, 830–847.

Bryk, A. S., & Schneider, B. (2002). *Trust in schools: A core resource for improvement*. New York, NY: Russell Sage Foundation.

Bunch, G. C. (2013). Pedagogical language knowledge: Preparing mainstream teachers for English learners in the new standards era. In C. Faltis & J. Abedi (Eds.), *Review of research in education: Extraordinary pedagogies for working within school settings serving nondominant students* (Vol. 37, pp. 298–341). Washington, DC: American Educational Research Association.

Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Educational Evaluation and Policy Analysis, 30*(3), 203–235.

Coburn, C. E., Russell, J. L., Kaufman, J., & Stein, M. K. (2012). Supporting sustainability: Teachers' advice networks and ambitious instructional reform. *American Journal of Education, 119*, 137–182.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94*, S95–S120.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181–199.

Fathman, A. K., & Crowther, D. T. (Eds.). (2006). *Science for English language learners: K-12 classroom strategies*. Arlington, VA: National Science Teachers Association.

Gamoran, A., Anderson, C. W., Quiroz, P. A., Secada, W. G., Williams, T., & Ashmann, S. (2003). *Transforming teaching in math and science: How schools and districts can support change*. New York, NY: Teachers College Press.

Gamoran, A., Secada, W. G., & Marrett, C. B. (2006). The organizational context of teaching and learning: Changing theoretical perspectives. In M. T. Hallinan (Ed.), *Handbook of research in the sociology of education* (pp. 37–63). New York, NY: Kluwer Academic/Plenum.

González, N., Moll, L. C., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Mahwah, NJ: Erlbaum Associates.

Heller, J. I., Daeler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching, 49*, 333–362.

Hewson, P. W., Kahle, J. B., Scantlebury, K., & Davies, D. (2001). Equitable science education in urban middle schools: Do reform efforts make a difference? *Journal of Research in Science Teaching, 38*, 1130–1144.

Hill, C. J., Bloom, H. S., Black, A. R., & Lipsey, M. W. (2008). Empirical benchmarks for interpreting effect sizes in research. *Child Development Perspectives, 2*, 172–177.

Janzen, J. (2008). Teaching English language learners in the content areas. *Review of Educational Research, 78*, 1010–1038.

Johnson, C. C. (2006). Effective professional development and change in practice: Barriers science teachers encounter and implications for reform. *School Science and Mathematics, 106*, 1–12.

Johnson, C. C. (2007). Whole-school collaborative sustained professional development and science teacher change: Signs of progress. *Journal of Science Teacher Education, 18*, 629–661.

Kennedy, M. M. (1998). Education reform and subject matter knowledge. *Journal of Research and Science Teaching, 35*, 249–263.

King, M. B. (2002). Professional development to promote schoolwide inquiry. *Teaching and Teacher Education, 18*, 243–257.

Knapp, M. S., & Plecki, M. L. (2001). Investing in the renewal of urban science teaching. *Journal of Research in Science Teaching, 38*, 1089–1100.

Lampert, M., Boerst, T. A., & Graziani, F. (2011). Organizational resources in the service of school-wide ambitious teaching practice. *Teachers College Record, 113*(7), 1361–1400.

Lee, O. (2005). Science education and English language learners: Synthesis and research agenda. *Review of Educational Research, 75*, 491–530.

Lee, O., & Buxton, C. A. (2013). Integrating science learning and English language development for English language learners. *Theory into Practice, 52*, 36–42.

Lee, O., Llosa, L., Jiang, F., Haas, A., O'Connor, C., & Van Booven, C. (2016). Teachers' science knowledge and practices with English language learners. *Journal of Research in Science Teaching, 53*(4), 579–597.

Lee, O., & Maerten-Rivera, J. (2012). Teacher change in elementary science instruction with English language learners: Results of a multi-year professional development intervention across multiple grades. *Teachers College Record, 114*(8), 1–44.

Lee, O., Maerten-Rivera, J., Buxton, C. A., Penfield, R. D., & Secada, W. G. (2009). Urban elementary teachers' perspectives on teaching science to English language learners. *Journal of Science Teacher Education, 20*(3), 263–286.

Loeb, S., Soland, J., & Fox, L. (2014). Is a good teacher a good teacher for all? Comparing value-added of teachers with their English learners and non-English learners. *Educational Evaluation and Policy Analysis, 36*, 457–475.

National Center for Education Statistics. (2006). *Data local education agency locale code file: School year 2005–06*. Washington, DC: U.S. Department of Education, Institute of Education Sciences. http://nces.ed.gov/ccd/pdf/pau051agen.pdf

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academy Press.

Parise, L. M., & Spillane, J. P. (2010). Teacher learning and instructional change: How formal and on-the-job learning opportunities predict change in elementary school teachers' practice. *The Elementary School Journal, 110*, 323–346.

Penuel, W., Riel, M., Krause, A., & Frank, K. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record, 111*(1), 124–163.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Thousand Oaks, CA: Sage.

Raudenbush, S. W., Spybrook, J., Congdon, R., Liu, X., & Martinez, A. (2011). *Optimal design software for multi-level and longitudinal research (Version 2.01) [Computer software]*. www.wtgrantfoundation.org

Rivera Maulucci, M. S. (2010). Resisting the marginalization of science in an urban school: Coactivating social, cultural, material, and strategic resources. *Journal of Research in Science Teaching, 47*, 840–860.

Roehrig, G. H., Kruse, R. A., & Kern, A. (2007). Teacher and school characteristics and their influence on curriculum implementation. *Journal of Research in Science Teaching, 44*, 883–907.

Rosebery, A. S., & Warren, B. (Eds.). (2008). *Teaching science to English language learners: Building on students' strengths*. Arlington, VA: National Science Teachers Association.

Smith, P. S., Nelson, M. M., Trygstad, P. J., & Banilower, E. R. (2013). *Unequal distribution of resources for K-12 science instruction: Data from the 2012 National Survey of Science and Mathematics Education*. Chapel Hill, NC: Horizon Research.

Solano-Flores, G., & Nelson-Barber, S. (2001). On the cultural validity of science assessments. *Journal of Research in Science Teaching, 38*, 553–573.

Spillane, J. P., Diamond, J. B., Walker, L. J., Halverson, R., & Jita, L. (2001). Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject. *Journal of Research in Science Teaching, 38*, 918–940.

Spillane, J. P., & Thompson, C. (1997). Reconstructing conceptions of local capacity: The local education agency's capacity for ambitious educational reform. *Educational Evaluation and Policy Analysis, 19*, 185–203.

Supovitz, J., Sirinides, P., & May, H. (2010). How principals and peers influence teaching and learning. *Educational Administration Quarterly, 46*(1), 31–56.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963–980.

Tuerk, P. W. (2005). Research in the high-stakes era: Achievement, resources, and no child left behind. *Psychological Science, 16*, 419–425.

Weiss, I. R., Banilower, E. R., McMahon, K. C., & Smith, P. S. (2001). *Report of the 2000 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.