1-4-2022

Conflict of allegiance: Professional development challenges in transforming science teachers' identities and practices

Elizabeth B. Lewis
University of Nebraska-Lincoln, elewis3@unl.edu

Conflict of allegiance: Professional development challenges in transforming science teachers' identities and practices

Elizabeth Lewis

Department of Teaching, Learning & Teacher Education, University of Nebraska-Lincoln, Lincoln, Nebraska

Correspondence — Elizabeth Lewis, Department of Teaching, Learning & Teacher Education, University of Nebraska–Lincoln Lincoln, Nebraska, 68588; elewis3@unl.edu

ORCID

Elizabeth Lewis http://orcid.org/0000-0002-3429-3003

Abstract

Case studies of two biology teachers, Cathy and David, from the same minority-majority, urban U.S. high school, provide insights into their instructional practices while they engaged in long-term professional development (PD). Findings suggest why science teachers engaged with PD may, or may not, adopt more adaptive pedagogical approaches in the service of reform-based teaching. Gee's institution- and affinity-identity constructs were used as analytic lenses regarding teachers' perceptions of teaching, learning, and agency in the dual contexts of their school's institutional environment and PD community. Over time, Cathy adopted more inquiry-based instructional practices she learned through PD seminars in building a scientific classroom discourse community with her majority Latinx students. Her professional identity and teaching became more aligned with the more progressive teaching philosophy and instructional practices promoted by the PD affin-

Published in *Journal of Biological Education* 2022
doi:10.1080/00219266.2021.2006267

Published 4 January 2022.

ity group. While David understood and enjoyed the PD, ultimately, he minimally adopted new strategies, adhering mainly to his pre-PD mode of direct instruction, staying within the strict culture of accountability of his school's administrative priorities to raise state test scores. These cases demonstrate why some teachers of diverse students are adaptive adopters of reform-based instruction through new affinity group membership, while others demonstrate greater allegiance to their institution-aligned identities.

Keywords Biology teachers, professional development, professional identity, scientific classroom discourse community, NGSS

Introduction and rationale

The preparation and ongoing professional development of effective teachers is a priority for science education reform. However, recognition of teacher learning as a key aspect of school reform is a relatively new phenomenon (Wallace and Loughran 2012). Until recently teacher educators and in-service professional development (PD) providers have had a limited understanding of how teachers apply what they learn from PD to their classrooms (Luft and Hewson 2014; Hewson 2007). In the last decade, science education researchers have made greater efforts to study PD effects on teachers' knowledge and how it may subsequently affect students' learning in science (van Driel et al. 2012). Teachers' instructional practices as measures of enacted learning are affected not only by content and pedagogical knowledge, but also by teachers' beliefs about teaching and learning. Teachers' beliefs and perspectives on their teaching are in a constant state of flux, which complicates studying how in-service teachers learn from PD, reflect upon their teaching practices, and implement new teaching innovations.

While teacher PD holds the promise of improving student understanding of science concepts, unless researchers understand the perspectives and internal filters teachers apply to PD-based learning, especially in conjunction with their pre-existing knowledge and resulting instructional decisions while interpreting external pressures (e.g. educational policy, testing mandates), student achievement cannot be expected to improve automatically. Through research, we can tap into common facets of teachers' beliefs (Tschannen-Moran & Hoy 2001) and identity (Avraamidou 2016) and, consequently, agency (Lasky

2005). Clear empirical findings are especially important in light of pressures with rising neoliberalist priorities in a capitalist society (Nasir et al. 2016). Additionally, the culture of accountability (e.g., *No Child Left Behind*) that has dominated the U.S. educational landscape for nearly 20 years has challenged how politicians and the public perceive teachers' roles as professionals. While policy is an easily identifiable aspect of educational systems, the mere act of setting standards and assessment neither ensures that intended objectives will be attained, nor how teachers can be encouraged to iteratively examine their teaching practices.

Prioritizing equity in science teaching

Teachers are vital actors in fostering connections between the academic culture and language of science and students' everyday attachments to popular culture and personal identities, which in turn are influenced by gender, race/ethnicity, and socioeconomic status (SES) (Hand et al. 2003). An identity-based research framework can facilitate investigation into the learning process (Brown 2004; Carlone, Scott, & Lowder 2014) and connect the phenomena of students learning science with teachers learning effective instructional practices. Teachers must understand their diverse students' everyday lives, especially in urban settings (Fraser-Abder, Atwater, & Lee 2006), to provide more meaningful connections within a science curriculum and to deliberately select instructional approaches that will broaden student learning opportunities. For example, research has shown that teachers who learn how to use linguistically diverse students' funds of knowledge (Faltis & Valdes 2016; Moje et al. 2004; Moll et al. 1992) support higher levels of engagement and learning during science lessons. In summary, in teaching and learning, understanding one's own identity, motivation, and beliefs are important for intellectual and dispositional growth, just as developing an identity allows one to be recognized as 'X' (i.e., a 'good' teacher) (Gee 2005) and be accepted into a community of 'X' (i.e., a learning community to become a more effective teacher) (Wenger 1998). Critically. science teachers need to be empowered to transform their professional identities through PD and demonstrate adaptability in employing new ways to teach all students.

This study was designed to investigate the ways, and the degree to which, science teachers did, or did not, use a PD model of reformed science teaching with their minority-majority (Latinx) students – specifically, how they chose to build a scientific classroom discourse community. In a previous study (Lewis, Baker, & Helding 2015), we focused on analyzing the growth of a large group of teachers in the PD program, and found: (a) that they had a positive desire to change their teaching practices to be more aligned with the PD program; (b) teachers perceived both barriers to, and supports for, implementing instructional strategies from the PD; (c) which instructional strategies teachers used most and least often; and (d) that the longer teachers engaged in the PD program, the more their instructional practices changed. This study is a comparative case study of two biology teachers who participated in the long-term PD program and focuses on their motivations, beliefs, and instruction during one academic year. The purpose of this study is to provide insight into how science education standards (e.g., the U.S. *Next Generation Science Standards*) can be supported through teacher PD. This study is important because in our previous research we found that those teachers who worked in lower SES schools started the PD program with more traditional, didactic practices than teachers who taught in higher SES communities. A deeper understanding of teachers who can be effective teachers of diverse, as well as historically marginalized, students is critical to the success of equitable science education priorities.

Theoretical and conceptual research framework

Several ideas were employed to construct a conceptual framework with strong theoretical underpinnings for this study. First, Lave and Wenger's (1991) theory of situated learning through the process of legitimate peripheral participation was critical to understanding teacher learning. Additionally, a focus on Wenger's (1998) communities of practice attended to the PD context in which teachers were learning new ways to teach science together. Situated learning frames the sociocultural setting of teachers' learning while they were engaged in PD activities. Finally, identity was used as an analytic lens (Gee 2001) to better understand teachers' dual contextual membership roles in their home institutions (i.e., school and classroom) and in off-site PD pro-

gram seminars. Wenger (1998) defines 'identity in practice' as a rich and complex set of relationships such that identity is: (a) a lived experience, negotiated as a way of becoming; (b) social through community membership; (c) a learning process; and (d) a nexus of multiple forms of memberships requiring a process of reconciliation across contexts. By analyzing teachers' stances towards, and statements about, teaching science, insight was sought into their professional identities as connected to their instructional and discourse practices with diverse students. Through convergent or divergent school and PD cultures, teachers can either respectively adopt or resist PD objectives and the support, or lack thereof, by administrators, and positive and negative events at their schools can encourage or discourage growth of 'identity in practice.' **Figure 1** illustrates the dynamic integration of situated learning theory and teachers' perspectives, beliefs, and identities within multiple contexts of PD, schools, and classrooms. Ideally, teachers can function fully and interact with agency in both settings, one common to all teachers in the PD program and one unique to their own classrooms. Teachers' classrooms are set within the culture and norms of school and district policies. As teachers move from

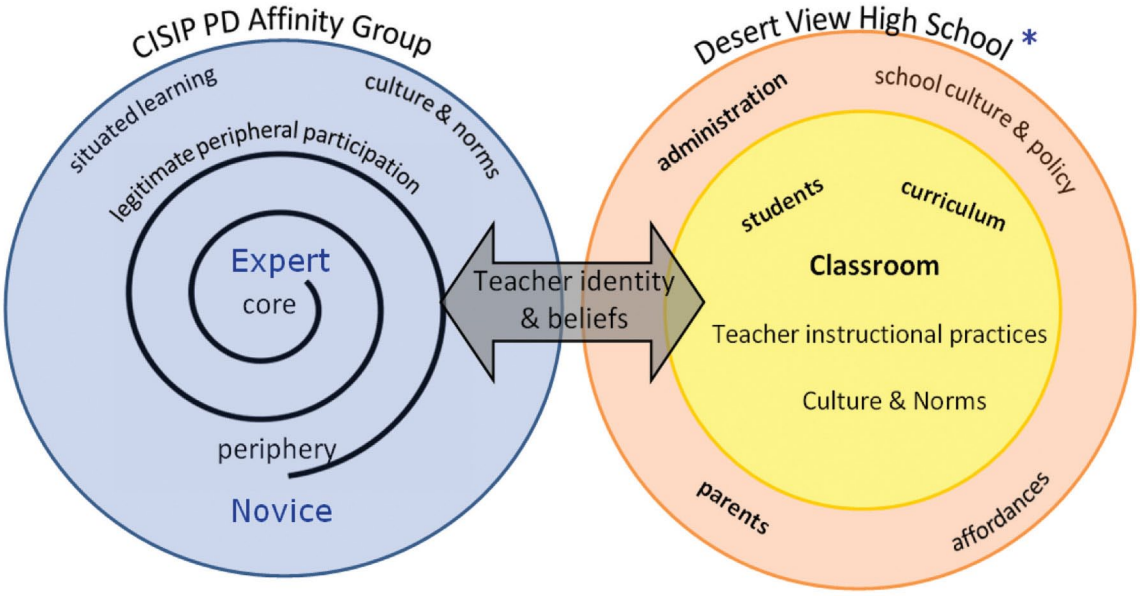

Figure 1. Conceptual framework of dual contexts of CISIP professional development and teachers' classrooms as teachers learn how to build a scientific classroom discourse community.

the PD setting with emerging affinity identities to their schools, they may adopt new ideas that can affect their classroom cultures, norms, and instruction. Concurrently, teachers bring their institutional perspectives, experiences, and identities, developed through social interactions at their schools with administrators, other teachers, students, and parents, to the PD affinity group. It is possible, to some degree at different points in time, that teachers may find their two identities to be aligned or in conflict with one another. When dissonance occurs it can be overwhelming, resulting in rejection, or alternatively embraced based upon a teacher's degree of innovation, creativity, or how thoughtfully adaptive she may be (Fairbanks et al. 2010). However, just as an effective teacher uses discrepant events to pique students' curiosity, effective teacher PD communities must support teachers' self-reflection and questioning (Loucks-Horsley Stiles, Mundry, & Hewson, 2009).

Background literature

Teacher professional identities

How identity forms behavior and functions has been studied from psychological, sociological, and anthropological perspectives. In psychology, James (1890) focused more on the individual, and Erikson (1950) on relationships between the individual and the socio-cultural environment. Mead (1934) addressed the social and cultural conceptualizations of self and identity from the traditions of sociology and anthropology (Roeser, Peck, & Nasir 2006), focusing on the construction of social identity. Wenger (1998), in proposing a social theory of learning, identified social participation as a primary focus and 'the process of being active participants in the practices of social communities and constructing identities in relation to these communities' (p.4). Thus, identity is complex and interactive between the self and others over time. Wenger defines identity within a social theory of learning as 'a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities' (Wenger 1998, p.5). The case studies presented here are framed using the construct of teacher professional identity to understand how science teachers perceived and enacted learning from a specific PD context.

Teachers build their professional identities over time with their colleagues, students, administrators, and communities throughout their careers. Rushton and Reiss (2020) reviewed findings from 20 years of empirical and theoretical publications (n = 79) on secondary science teachers' identity and identify 'the important role that shared identity and group membership play in developing and sustaining positive identities' (p. 141). Such empirical studies about teacher identity in science education demonstrate how identity has been used as a research construct in investigating teacher learning and development and catalogue supportive approaches to identity development. Avraamidou (2016) also noted the need for more studies of science teacher identity as a process, studies that connect teacher identity research and reform recommendations, and studies of teacher identity as it plays out in classrooms. This study lies at the intersection of all three gaps by focusing on science teachers undergoing PD and confronting their professional identities as they participated in a learning community and sought to improve their teaching of historically marginalized Latino/Latina/Latinx students.

Identity as an analytical lens

Gee (2001) proposed identity as an analytical lens for educational research. He outlined four ways to view identities: (a) 'Nature-identity, a state of being developed from forces in nature; (b) institution-identity, a position authorized by authorities within institutions; (c) discourse-identity, an individual trait recognized in the discourse/dialogue of/with 'rational' individuals; and (d) affinity-identity, experiences shared in the practice of "affinity groups"' (p.100). This study analyzes two biology teachers' professional practices with their diverse students and their perspectives and agency in changing how they taught. To understand their motivations, I interpreted their perspectives on the PD and their classroom behaviors through the dual lenses of institution- and affinity-identity.

Teacher learning communities and PD as an affinity space

There are multiple ways to design and enact teacher learning communities. As defined by Cochran- Smith and Lytle (2003) they are new,

and/or experienced, social groups of educators formed to learn new information, reconsider their previous knowledge and beliefs, and build upon ideas and experiences to improve practice and enhance students' learning (pp. 6-7). Teacher learning community elements, especially the exchange of ideas and peer critique, often become more apparent after teachers interact over time. Gee (2004) argues that while people can occupy the same affinity space, they may take away very different meanings from that space and the interactions that occur within it. It takes time and effort to build a community of learners (e.g., a PD workshop, a science classroom), whether those learners are teachers or children. Lave and Wenger (1991) acknowledged that 'there may very well be no such thing as an "illegitimate peripheral participant" . . . peripheral participation is about being located in the social world; changing locations and perspectives are part of actors' learning trajectories, developing identities, and forms of membership' (pp. 35–36). Consequently, by observing teachers' participation in PD, this study attends to: (a) the way teachers expressed their learning about the PD model and using new instructional strategies; (b) how they talked about their roles with colleagues in their school-based teams; (c) their view of their roles as teachers; and (d) their perceived support and challenges to implementing new instructional approaches and strategies.

Workplace compliance and collaboration

The teaching profession continues to struggle with establishing its professional status (Ikoma 2017). Teachers occupy dual roles as professional educators and employees who are expected to comply with their school district's expectations. Historically, in the U.S. women have been recruited as teachers because they could be paid less than their male counterparts (Kafka 2016). Unfortunately, the residual effects of a field dominated by women in a society that still underpays women (Barroso and Brown 2021) serves to maintain a hierarchical culture of compliance in modern K-12 educational settings. Thus, it is critical to study what happens to teachers' perspectives and decision-making as they experience PD that challenges them to act outside of their school's norms, especially if their school culture defaults to, and requires teachers to submit to, traditional teaching modes, rather than

encouraging teachers to create rich learning opportunities to serve the needs of diverse students. Because reform-based teaching does not occur in a vacuum, we must also understand how teachers perceive and communicate their own learning experiences and educational priorities with their colleagues as part of a PD learning community.

Teacher change in the face of curricular stability

A teacher's knowledge, professional beliefs, teaching self-efficacy, attitude, identity, and resultant instructional practices reflect how they orient their teaching philosophy within teaching contexts and participation in teacher learning communities. The phenomenon of teacher change or stability, through teachers' agency and affordances, is complex and situated in the larger contexts of schools and, in this case, off-site PD settings. Cuban (1976, 1992) described curricular stability and change throughout the 20th century and the forces that affected it. He attributed this stability to the 'socializing functions of schools' (1976, p. 4), national performance tests, educational legislation, and the conservative nature of teaching. Cuban (1992) also described external and internal forces as producing only incremental, rather than fundamental, changes in the intended curriculum by teachers. Thus, the challenge that faces the science education community is how to provide teacher PD that meets the directive of science education reform, and also works to displace a sociocultural, historical system that has resulted mainly in institutional stability and resistance to reform. The *Next Generation Science Standards* (NGSS, 2013) continue the national call for diversity, equity and inclusion of students (Carter and Darling-Hammond 2016) in science in the U.S.

To enact change at the institutional level, there must be a focus upon the interaction of students, teachers, schools, and policymaking, i.e., *How does institutional school culture affect a teacher's agency, and does it affect all teachers in the same school in the same way?* The study presented here followed two white, middle-class science teachers from the same urban, Latinx minority-majority high school as they engaged in long-term PD while concurrently attempting to incorporate aspects of the PD program into their teaching practices. This study's findings provide some broader, transferable insights into science teacher learning and progressive instructional changes.

Urban science education and addressing equity through professional development

The urban school setting of this study was a purposeful choice. Urban schools in large metropolitan cities have greater student diversity with additional challenges of higher rates of poverty, attrition, and a less stable teacher workforce than suburban, middle-class schools (Carver-Thomas & Darling- Hammond 2017; Barton, Tan, & O'Neill 2014). Every day teachers are called upon to bridge students' mainstream culture and personal identities influenced by gender, ethnicity, and SES. In their own lives, teachers may not have had much experience with diverse youth and/or may not have been adequately prepared through their teacher preparation programs. This is because the demographics of the teaching force, largely white, middle-class, and female (80%) does not align with the increasing diversity of the U.S. student population in which over 40% of school-aged children are considered minorities and over 20% live in poverty (Carter and Darling-Hammond 2016). As Gee (2005) asserts, 'the fact that people have differential access to different identities and activities, connected to different sorts of status and social goods, is a root source of inequality in society' (p. 22). With the significant increase in student diversity in U.S. schools and classrooms, science teachers need to be well-prepared to work with ethnically and linguistically diverse students to foster science learning for all (Faltis & Valdez 2016). Science teachers who improve their instructional knowledge base and knowledge of diverse students' learning needs are better equipped to reduce inequalities more often seen in lower SES groups, resulting in the student achievement gap long seen in the U.S. (Berliner 2006).

Language-based aspects of science teaching and learning

Students' language and culture affect their learning in science. Lee, Quinn and Valdez (2013) proposed that 'when students, especially ELLs, are adequately supported to "do" specific things with language, both science learning and language learning are promoted' (p. 2). In reviewing the NGSS framework, Lee, Quinn, and Valdés (2013) identified four critical language-based practices beneficial to fostering science meaning-making and language development: (a) devel-

oping and using models; (b) constructing scientific explanations and designing engineering solutions; (c) engaging in argument from evidence; and (d) obtaining, evaluating, and communicating information. These practices are not new, but the challenge of providing inclusive science education for multilingual learners demands that teachers provide comprehensible lessons that transcend mere vocabulary attainment. This study's PD context included a strong focus on language-based aspects of science learning.

Research context and methodology

Context: Teacher professional development as a community of practice

The goal of the National Science Foundation-funded *Communication in Science Inquiry Project* (CISIP) was to teach secondary teachers how to build scientific classroom discourse communities (SCDC) in their diverse science and English language arts classes (Lewis et al. 2016, Lewis, Baker, & Helding 2015). Areas of emphasis included in the CISIP model were scientific inquiry, oral discourse, written discourse, academic language development, and learning principles (National Research Council [NRC], 2000; NRC, 2005). Student learning was central in the model, in an inquiry-based environment that fostered verbal and written scientific communication (Lewis, Baker, & Helding 2015). Academic language development was a key component of learning science as many scientific terms and concepts have different meanings as compared to students' everyday understanding and language use. Teachers who use interactive discourse and science inquiry instructional strategies can engage diverse students in the language-based learning activities identified by Lee, Quinn, and Valdés (2013) to support science concepts and skill acquisition. Learning principles, from cognitive research (NRC 2000; NRC 2005), emphasized the critical role of accessing students' prior knowledge, importance of facilitating factual and conceptual understanding, and benefit of students' self-monitoring to process and reinforce their learning.

The CISIP program was designed for a full year, beginning with a three-week summer teacher PD institute. Numerous previous par-

ticipants from the development phase stayed for a second year, acting as workshop session facilitators and mentors to the next cohort of teachers in the CISIP community of practice. To foster the process of shifting to more reform- and inquiry-based instructional practice, the PD was designed to help teachers practice and develop an affinity identity as a 'CISIP science teacher'. In consideration of Gee's identity definitions, a prototypical CISIP teacher: (a) teaches from the stance that student learning is vital, using a wide range of research- based oral and written discourse strategies (e.g., argumentation) to help students be active science learners; (b) understands the nature of scientific inquiry and communication and constructs open- ended science lessons to engage students in scientific investigations and communicate their findings; (c) knows how to probe for students' understandings, prompting them to explain how they know what they know and to evaluate a situation in which there is no one right answer; and (d) thoughtfully adapts in response to the challenges students experience in learning science. By studying two teachers' journeys through PD and their year in the classroom, we can learn more about how teachers become and get recognized as a CISIP teacher.

Research approach

I adopted a holistic, interpretivist (Erickson 1986) view towards teacher experiences and perspectives and their use of PD, relying upon my understanding of the PD program, teacher interviews, classroom observations, and teacher self-reports. Employing multiple means for understanding the phenomena within an overall qualitative approach, I used techniques such as open coding and building assertions from small pieces of data that allowed for triangulation and the generation of assertions. Generating two case studies (Yin 1994) allowed me to describe and compare the social and pedagogical actions in specific teachers' classrooms and what these actions meant to those teachers (Erickson 1986). I also used Miles and Huberman's (1994) approach to data processing, analysis, and presentation of findings. My analysis led to conclusions about interactions between teachers' learning during the PD program, their evolving professional identities, and their institutionally mediated agency in the classroom.

Researcher statement

In studying teacher PD, I am aware of my own identity as an educational researcher, teacher educator, and former high school science teacher and the high value I place on teachers' professionalism. As a teacher I sought professional credentials and these experiences shaped my attitudes and beliefs about reform-based science instruction. As a teacher educator I believe that improving teachers' professional knowledge is good for students as well as teachers. As an educational researcher I have observed hundreds of science lessons. During my role as a researcher on this project I made every effort to suspend my critical inner voice and adopt the attitude that the teachers I observed and interviewed were experts in their classrooms who knew their students better than I did through their shared lived experiences.

Entering the field and understanding the phenomenon

As I immersed myself in the PD workshops and teachers' classrooms, I wondered if the degree to which teachers used the instructional model was connected to their professional identities as teachers, perceived agency, and beliefs about how students learn and how science should be taught. I anticipated that analysis of a teacher's professional perspectives through both institution and affinity identities could reveal (mis)alignment between these two facets of identity, thus allowing concurrent consideration of the dual contexts of the PD and classroom. Consequently, I generated the following research questions for this study: (1) *In what ways did teachers adapt the PD model of a scientific classroom discourse community to teach their diverse students?* and (2) *How was a teacher's institution- and affinity-identity expressed through their actions and perspectives of teaching and learning science?*

Data sources and methods of analysis

Purposeful selection of the two case study teachers occurred through their participation in an ancillary study (Baker et al. 2009; Lewis, Baker, & Helding 2015) of science teachers' use of reform-based PD. In that preceding study there were two level of participation. First, Group 1 (n = 25) consisted of all secondary science teachers who

participated in the CISIP program. These teachers completed a self-reflection survey twice, pre-/post-PD, on how often they used and would like to use specific CISIP strategies. The 20-item survey for teachers to consider their teaching with respect to the key program elements was designed by the PD leadership and research team. We also administered a 46-item survey on six categories (i.e., *administration, collaboration, curriculum, instruction, parent*, and *student behaviors*) of possible supports and barriers to implementing the PD instructional strategies. Concurrently, Group 2 (n = 15), which consisted of a subgroup of Group 1 secondary science teachers who consented to regular classroom observations, were observed teaching science lessons. These teachers' classroom activities were coded using the 36-item *Discourse in Inquiry Science Classrooms* (DiISC) classroom observation instrument, which was developed over three years and aligned to the PD and instructional strategies (Baker et al. 2008). Finally, using hierarchical linear modelling, one- and two-year exploratory longitudinal models were built from the DiISC scores to determine if any significant relationship existed between various teacher characteristics, systemic factors, and teachers' degree of PD implementation (Baker et al. 2009; Lewis, Baker, & Helding, 2015). We found that the rate of change in teachers' use of reform-based instructional strategies was significantly affected only by the length of time they had spent in the PD program; however, their initial use was determined by the SES of their school, i.e. lower SES student population correlated with more traditional teaching. This result suggested that some negative beliefs about diverse students affected teachers' decisions about the degree of reformed-based teaching they enacted. Thus, further investigation was warranted to investigate this relationship and adopting a case study approach is a common approach to such an inquiry.

Case selection

From their participation as Group 1 and 2 teachers, I selected two high school biology teachers based upon their observed divergent classroom instructional practices over the course of the academic year. I purposefully chose these two teachers to serve as comparative case studies (Yin 1994) to connect their similar PD experiences and goals

with their classroom instruction and selected activities. Teachers were asked when they would be using the CISIP approach to teaching science and eight to 12 visits were completed. Formal, semi-structured interviews were conducted towards the end of the PD program.

Cathy and David both taught biology at 'Desert View', an urban high school in a metropolitan southwestern U.S. city with a high percentage majority-minority (86% Latinx) and socioeconomically disadvantaged students (59% free or reduced lunch). Both were white, middle class career changers. Cathy taught honors and college preparatory biology classes and David taught general biology with many students with identified special needs. Cathy had taught for 10 years and David for five years prior to the PD program. They shared neighboring classrooms, were collegial, and conferred daily. Both were active and positive participants in the PD. These teachers also represent a typical division of high school teachers' teaching assignments and the different teaching challenges they faced. While it would have been highly informative to have a Latinx teacher in this study, unfortunately there were none in the PD program to recruit.

Case study results

Institutional culture and priorities

State-level testing was a major concern for Desert View High School. The school had a history of standardized test performance fluctuating around the minimum acceptable performance level, and the state had recently added a science test, adding even more pressure to improve student test performance each year ([State] Department of Education, 2008). Many diverse and low SES students struggled on state-level assessments. The administration was ever-vigilant regarding test scores, requiring test-prep warm-up activities in each class outside daily science lesson content. When it was time for state tests the school went into high gear (Appendix, *Vignette #1*), providing Saturday classes for students who had previously failed state competency tests; thus, meeting the state's annual improvement goals for the district.

From teacher interviews, observations of classes, and school reports, the school's leadership encouraged test-prep curricula rather

than standards-aligned inquiry-based science teaching. The school's main concern was having enough students pass the tests, and less consistently on encouraging learning through rich and varied experiences. In case study #1, Cathy's classes began to diverge from this institutional stance once she participated in PD. However, in case study #2, David's classroom culture continued to be one of managerial compliance, with direct instruction and skill- drill strategies aimed at the lowest performing students in the hope that they would pass the tests and raise the school's overall performance. These assertions are warranted as follows.

Teachers' use of professional development SCDC instructional strategies

Adopting more inquiry-based approaches to teaching science from the PD program would be evidence of teachers' shifting professional identities, or identities in process, and more in line with the affinity-identity of a 'CISIP teacher'. Thus, the specific instructional strategies Cathy and David used most often in their science lessons were documented. Upon observing them teach over many class periods and based upon the lesson codes generated using the DiISC observation instrument, it became apparent that on average David was not using the SCDC instructional strategies as much as Cathy. Detailed examples of each teacher's instructional practices are presented in the Appendix (*Cathy Science Lesson #1* and *David Science Lesson #1*). Compared with the PD's teacher-mentors and the new participant group to which she belonged, Cathy's implementation (M = 32.54, SD = 9.46) was between the two groups' averages, while David's (M = 19.22, SD = 9.90) was below the new participants' average (**Table 1**). The major classroom discourse characteristics of Cathy's (e.g., small group peer-to-peer discourse) and David's (e.g., whole group IRE discourse) observed lessons and typical activities are presented in **Table 2**. In general, Cathy's lessons included a wide range of guided inquiry lab activities with students recording data and using whiteboards in their small groups. Despite the PD, David's lessons were usually restricted to note-taking and completing vocabulary-based worksheets.

Table 1. Cathy and David's mean classroom observation scores by scale and raw points.

	Cathy (*n* = 13 lessons)		**David** (*n* = 9 lessons)	
DiISC Scale (number of items)	**Mean**	**SD**	**Mean**	**SD**
Scientific Inquiry (*n* = 6)	0.56	1.00	0.24	0.51
Oral Discourse (*n* = 5)	1.28	1.01	0.67	0.74
Written Discourse (*n* = 6)	0.82	1.02	0.72	0.76
Academic Language (*n* = 8)	1.05	1.04	0.65	0.77
Learning Principles (*n* = 11)	0.86	0.88	0.44	0.64
Total mean DiISC score (out of a possible 108 points)	32.54	9.46	19.22	9.90
All new participants	**25.04**	**10.86**		
All previous participants	**38.96**	**11.68**		

Table 2. Classroom discourse structures and examples of typical activities.

Cathy's Honors Biology Class	David's General Biology Class
Discourse structure	**Discourse structure**
• Small student groups used frequently • Cathy talked in a whole group setting, but mainly to give directions and probe students for their understanding as they worked	• Teacher often used direct instruction • David's talk (IRE) dominated the class during whole group instruction and students rarely talked to each other
Typical Activities	**Typical Activities**
• White board discussions • Guided inquiry labs • Recording data, small group discussions, and research notes recorded in science notebooks • Student presentations	• Bell work: Vocabulary practice • Note-taking from lectures (cloze notes) • Worksheets taped into the science notebook • Guided inquiry labs • Vocabulary quizzes

Cathy: Observing desired change in process

Halfway through the 12 observations of her teaching, Cathy confessed that she 'wasn't using any CISIP today' because she noticed that CISIP methods took more time, and she was behind schedule. Cathy's acceptance of a reform-based approach to teaching science was negotiable when she became concerned about institutional priorities be-

cause she viewed inquiry-based science lessons as too time-consuming. However, Cathy also said she was trying not to let time discourage her, acknowledging that her students were learning better with this new approach. She also commented that she did not use as much CISIP with her 'regular' biology classes. All students used science notebooks, but she was not trying as many 'CISIP-ed lessons' with those students as she was with her honors classes. This suggests that she had not yet fully embraced constructivist learning experiences as an effective means for supporting struggling learners.

Using PD strategies effectively

Cathy's most CISIP-aligned lessons relied upon strategies for establishing a SCDC. Early in the year, in small groups students engaged in a project at the library to explore the history and scientists who developed cell theory. This lesson received a high DiISC score of 48 points. Through this inquiry- based activity, students engaged with the nature of science and how scientific knowledge changes over time, writing responses in their notebooks to the question: *'How did each scientist's work influence the next scientist's work in discovering the cell theory?'* In another high-scoring lesson, Cathy used a PD model activity that involved teacher modelling of argumentation, specifically how to write claims and evidence, to help students understand how to construct strong scientific explanations. Engaging students in writing claims aligns with NGSS Dimension 1, scientific practices, specifically 'constructing explanations and engaging in argument from evidence'. Cathy's students highlighted the reasoning in the example arguments. Then, in pairs, students revised their explanations from the previous day's egg osmosis activity on a whiteboard. The students read all the whiteboards, gave feedback on the other groups' claims about decalcified eggs' reactions when soaked in water and syrup. Students then revised their own claims in their science notebooks.

Overall, Cathy's lessons are strong examples of how teachers used PD strategies and materials to facilitate students' learning through argumentation. While Cathy used some direct instruction, she was modelling clear expectations for writing scientifically to prepare them for this task. Cathy also successfully replicated other lessons modelled in

the PD. She commented that even if it took more time, she believed using a constructivist approach helped students learn better, even if pressed for time. These science lessons often allowed for more peer-to-peer discourse.

Mixed results using PD instructional strategies

Cathy tried new ways of structuring discourse with her students. Her most CISIP-aligned lessons were on genetic mutations, in collaboration with the school librarian and PD team member, Sharon. At the beginning of the project, Cathy commented that this way of teaching was very different from how she was accustomed to teaching, and she hoped it would work. While optimistic about the new approach, she was not yet confident. The gene mutation project built upon a classroom culture of clearly communicated expectations. Cathy and Sharon empowered and challenged students to find an interesting scientific topic, form groups around common interests, negotiate a common topic, and justify their choices prior to starting their research. Cathy said that before the PD she would never have brought students to the library to do research, but because Sharon understood the instructional goals Cathy was working towards, she could support both teacher and students with something new. (**Figure 2** illustrates the findings of this study's school-based team and their interacting professional identities and peer influences.)

Cathy's students regularly engaged in peer-to-peer discourse and were learning to defend their decisions while practicing their reasoning skills. Allowing students to choose their research topic gave them agency, and the content expectation was not lost, because ultimately all students were expected to demonstrate that they understood genetic mutations. The project aligned with *NGSS HS-LS3-2 Heredity: Inheritance and Variation of Traits*, specifically: 'Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis; (2) viable errors occurring during replication; and/or (3) mutations caused by environmental factors'.

Cathy was enthusiastic about teaching this new project and it reflected an adaptive stance towards redesigning existing curriculum to be more engaging for all students. However, her effort to try a novel

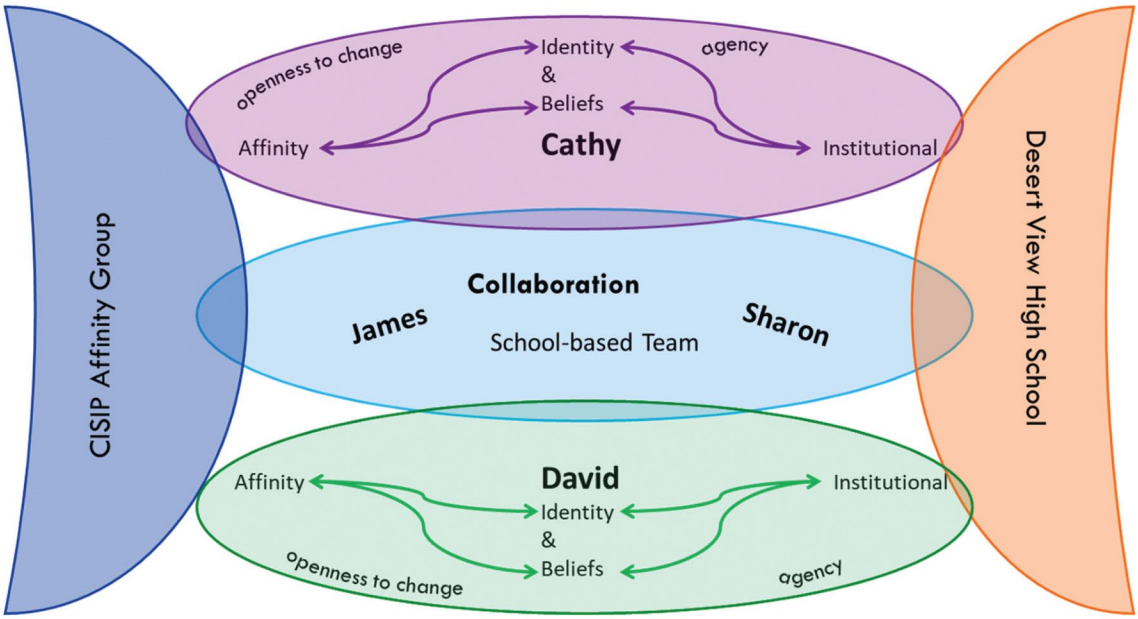

Figure 2. The diagram shows the relationships of the two case study teachers with their school-based team and affinity and institutional spaces. [* = *pseudonyms were used for all participants and locations*]. Cathy and David are the case study teachers and Sharon, school librarian, and James were their school-based colleagues in their PD team.

approach was not without frustration. After observing some students struggle to present their genetics research projects Cathy commented that she had not realized her students were not accustomed to presenting formally. She assumed, because they presented in their other classes, they would be sufficiently prepared to give a science presentation. This speaks to: (a) students' need for scaffolding discipline-specific oral discourse tasks with which they may be unfamiliar; (b) helping students listen and ask higher-level questions; and (c) providing opportunities in PD for teachers to debrief lessons with students. Without such support, teachers may assume their students are incapable and consequently stop trying new practices. In this example, Cathy struggled with her shifting instructional approach and professional identity. She tried something new that she believed would work and then not all went to plan. Cathy took a risk by allotting more time to the genetics topic than in the past, and because her students struggled with this new approach, she worried that they may not have learned the science content. There was a real possibility that she would re-

ject her new reformed-based stance, a vulnerable affinity identity she had initially enthusiastically embraced. Fortunately, in the PD workshops Cathy discussed this with other teachers and received the encouragement she needed.

David: Managing student compliance with school test-prep culture

I observed David's teaching nine times until I had captured the range of his instructional practices. David routinely engaged students in warm-up questions when they arrived each day. At the first observation, David posed unrelated science trivia questions; at the second observation, the daily questions related to the science topic they were studying. In two later observations, half the questions were on science content (i.e. mitosis, ecology) and half on Christmas trivia. David had arrived at a compromise between providing students with a review or preview of science vocabulary words and required test-prep, non-science questions. David reported that the main purpose of the non-scientific vocabulary questions was for state test preparation; the review was often conducted by a special education co-teacher.

Minimal trial with PD materials and reverting to direct instruction practices

During one classroom observation, David used materials from his colleague's Cathy's cell organelle diagramming activity. However, while Cathy used small group discourse strategies from the PD to have students discuss, David's students worked alone. In another lesson David used a more CISIP-like approach, pairing students to discuss their answers during an exploratory textbook activity. David tried to have students work together and use whiteboards to summarize their ideas, a major departure from a dominant structure of individual student work. The most inquiry-based lesson, in which David had the students collect data on decalcified eggs, was a lesson he and Cathy had planned together with some advice from another CISIP teacher wherein students wrote a scientific investigation report with claims and evidence. Collaboration between the two teachers was productive and encour-

aged them to try something new with more reformed-based science inquiry elements. Sharing their ideas at the PD workshop also was supportive.

David's egg lab activity proved to be an atypical lesson. Time and again he relied upon worksheets and bell work that engaged students in low-level problem solving and recall. Additionally, often when David used worksheets, he not only modelled how to do the problems, but also had students write the answers he gave verbatim for every problem. He seemed to have low expectations that his students were capable of doing the work or did not trust that they would do the work independently, stating that 'some students don't care.' The emphasis was always on students getting the right answer – which may also have led them to (mis)understand the nature of science as an unchanging body of knowledge. David stated that the main purpose of most of his science lessons was so information could be memorized and recalled for a test.

A final observation of his teaching was of an evolution unit activity to model organisms' adaptation to new environments (Appendix, *David Lesson #2: Ensuring the Right Answer*). Throughout the lesson David talked through each step to ensure that students wrote all the information in the right spaces on their worksheets. His co-teacher, Martha, monitored students to ensure they followed directions. David told students what to write on their worksheets rather than allow students to work independently. Students were arranged in small groups, but their talk was limited to data collection rather than discussing what their data meant in terms of ecosystem adaptation. David did not shift responsibility for learning to his students. At the end, students turned in worksheets after answering a few rote questions.

Some of David's students had identified special needs and/or were multilingual learners, so their need for a well-organized lesson with academic language support was clear. However, most lessons did not include language support strategies (i.e. use of pictures, realia, and gestures). Rather, David's approach was to talk through the activity as written, a surprising tactic, especially considering that he had a special education co-teacher, Martha, who could have provided a variety of language support strategies. There appeared to be a tacit agreement between teachers and students, i.e., students only needed to

replicate what they were told and if they did not cause trouble, they would pass their science course. Students were being trained to follow procedures, as opposed to participating in a discourse community to explore and make meaning of science concepts. David expected compliance from his students, and the test-prep culture of the institution was supported through this student behavior and how they produced evidence of their learning. David's professional identity aligned more with his school's institutional priorities than with the CISIP teacher identity that was modelled and encouraged by the PD affinity group.

Cross-case comparison *of teachers' identities*

I compared teachers' interview statements with their teaching. In an interview focused on perspectives about learning new ways to teach science, Cathy said she used to think that when students were talking that they were automatically off-task, but this year after listening to students talk with each other she realized they were working productively. Recognizing the value of students' discourse to help them understand science concepts and trusting them to be on task was a significant change for her. She was now comfortable facilitating students' learning in small groups. In terms of affinity identity, Cathy could be recognized as a 'CISIP teacher', belonging to the ranks of teachers who applied the PD model to their classrooms. She could not only explain ways to change science lessons to be more effective, but also could provide examples from her own teaching as evidence of change.

While David could describe different CISIP-endorsed strategies, he continued to dominate classroom discourse and direct students through worksheet-based questions and activities. While he allowed students to help each other, he rarely assigned small groups and when he did, he still directed them by giving step-by-step verbal instructions, alternately confirming, and providing correct answers throughout the science lesson. For example, in a lesson on how to translate DNA code, two boys were working together and the one who understood was helping the confused student. David stopped these two students, and the whole class, so he could explain the decoding process (Appendix, *David Science Lesson #1: Dictating Discourse)*. By assuming control of the classroom discourse, David pre-

vented student discourse. This level of teacher control was counter to the social constructivist underpinnings of the PD program, but David was concerned about students 'goofing around'. The two boys were working productively together, a clear example of Vygotsky's (1986) zone of proximal development, with one explaining the decoding process to the other, and were in the process of making sense of DNA replication. By discouraging such interactions, David lost opportunities to build a SCDC with his students. In terms of Lave and Wenger's concept of legitimate peripheral participation, David was not able to move from the periphery of the CISIP affinity group to its core to be recognized as a CISIP teacher. He enjoyed the collegiality of the PD sessions, but his instructional approach did not lead to a shift in his professional identity beyond his institutional identity as a teacher of low-performing students whose test scores must be raised.

In an interview, David commented that in his first few years of teaching his students said to him, 'Is that all you do, worksheets?' He stated that he used them because 'that's all I knew.' Even post- PD, David's instruction still relied upon more traditional approaches; the CISIP model was a very different way for him to think about how to teach (See Appendix for *David Interview Excerpt #1*). Despite learning about more effective ways to teach science in the PD, David continued to focus on students' learning of science vocabulary, lectures, and notetaking as the core of his teaching practice. He reported that he did not have time to revise curriculum as well as make detailed comments on all of his students' work, so he did not try anything new for fear of not doing it well. While Cathy viewed her teaching practice as 'malleable and dynamic' and dove into new practices, David continued to teach mainly as he had, adopting only what could easily fit into his curriculum because more significant changes would take too much class time.

Factors that supported teachers' implementation of CISIP

Through interviews and their survey responses, Cathy and David's beliefs about students' academic abilities emerged to explain why they felt either supported or discouraged in changing their teaching practices to be more aligned with the PD model. They, as well as many

other teachers in the PD program, often talked about challenges associated with increased class sizes, insufficient time, more students with individualized education plans, and pressure to raise test scores. But more than anything else, they wanted more time. Teachers' comments during these interviews and their survey responses provided some additional insight into their perspectives and beliefs about teaching and learning.

Teacher beliefs and desire to change

Using the *CISIP Beliefs* survey results, I compared the difference between teachers' current and desired instructional practices associated with PD. In her pre-PD survey, Cathy's overall desired change from her current teaching practices (pre-PD difference = 43) was about twice that of David's (pre-PD difference = 21), indicating she was more open to, or perceived greater agency for, change to a much greater degree than was her colleague (**Table 3**). Through regular conversations with both teachers, they always commented on how much they enjoyed the PD, but Cathy took the lead in trying new instructional strategies and approaches with her students; her comfort level and motivation were evident in what she said and how she responded to the survey items. When asked to describe her teaching philosophy, Cathy said 'it's malleable, it's dynamic, [and] it's not static. To me, that's important, because if it starts getting static, I need to get out of this, because I'll get bored like that [snaps her fingers] . . . that's what I like so much about teaching science, especially biology, is that it's always changing.'

Table 3. Comparison of Cathy and David's pre- and post-PD self-assessment of their current and desired use of PD strategies in their instructional practice.

Measure	Cathy		David	
Pre-PD Current Practice	42	Difference:	55	Difference:
Pre-PD Desired Practice	84	84 – 42 = 43	76	76–55 = 21
Post-PD Current Practice	54	Difference:	49	Difference:
Post-PD Desired Practice	81	81 – 54 = 27	80	80–49 = 31

Additionally, Cathy prioritized students' habits of mind and life skills over the science content. She commented that it was just as important for students to learn 'responsibility, maturity, work ethics, personal ethics like honesty' as it was biology. Finally, Cathy stated pragmatic views about education, 'I see my students needing me to be here every single day. I see my students needing me to do my job, not just sitting at that desk . . . I see them needing that, because I know what happens when students don't get that'. Cathy commented wryly that, 'when students don't have teachers that teach, students know that they don't learn anything', and she did not want to be identified as 'one of those teachers'. Cathy's identity as a 'good teacher' was important to her. She not only wanted other teachers to recognize her as an effective teacher, but she also wanted her students to know that she cared about them and their education. This motivated her to change how she taught science even after teaching for 10 years.

David described several different factors that contributed to his teaching philosophy (Appendix, *David Interview Excerpt #2*). First, in a positive sense he recognized that students need to be engaged and he accepted that it was his job to engage them. Second, he stated that because of the CISIP program he now saw that his primary role was to teach kids how to think and solve problems as opposed to rote memorization; this was a positive shift in his awareness. But David also commented that his students struggled with problem solving and reading directions and 'shut down' when asked to do anything but memorize answers. While this may have been an accurate observation, it reflected a fatalistic view. Considering that the school was focused on state test scores and in this working-class community in which nearly 60% of students qualified for free or reduced lunch, it is not surprising that the default curriculum would be more procedurally oriented than constructivist. Anyon (1980) identified the hidden curriculum of work in schools, in which lower SES students were limited to following procedures. In a way, David's beliefs were like Cathy's in that he mainly viewed educational purpose as providing students life skills, but he held a restrictive view of what they were able to do and which were most capable of critical thinking.

Third, David described his teaching in highly structured, managerial terms, which recalls Taylor's (1911) cult of efficiency model of education. I observed David walking around the classroom with a clip-

board to mark students' participation points. David saw competition as an improvement over the past when his students were non-responsive, and while the alignment with CISIP was absent, there was some success, suggesting David's transition might simply take longer than Cathy's. For example, David was careful to be sensitive to students' feelings and did not want to embarrass shy students during whole group discussions by asking them to answer difficult questions. He had not embraced the use of small groups yet and defaulted to strategies that applied to a whole group setting, relying greatly upon direct instruction.

David commented that he was constantly trying to figure out how to motivate his students: 'because every kid is different. For some kids, it's calling their parents [that] is the magic pill. For some kids, it's detention. For some kids, they care about their grades.' And David often used external motivation, e.g. their future earning potential. While there is admittedly an economic value of staying in school, he did not use the CISIP strategy of bridging diverse students' funds of knowledge with the academic world to try to make science more relevant, interesting, and motivating to learn. David did not trust students to work together, and while he said that teachers need to get kids interested in science, he failed to make lessons more engaging, which also could have minimized potential off-task behavior and discipline problems. Ultimately, David seemed unwilling to change his procedural-driven lessons and managerial classroom management style; he valued a controlled environment and prioritized social goals for 'good' behavior rather than encouraging rich classroom discourse. In the institutional space in which David taught, he complied with expectations that the curriculum would be covered regardless of student interest.

Teachers' views of supports and barriers to change

The *CISIP Sources of Support and Barriers to Implementation* survey data provided some insight into teachers' views of six categories of sources of support and barriers to using the PD; *administrative actions, collaborative relationships, curriculum, instruction, students, and parents*. While most teachers in the PD identified more items as supportive in implementing the CISIP model, four items that most science teachers identified as barriers concerned parents and students.

Parents

David identified his students' parents' ability to help them with their written homework as a major barrier to his implementation of the PD strategies, while Cathy viewed this as neither a barrier nor a support. Because students were tracked into lower levels of biology in David's classes and higher levels in Cathy's, the two teachers' views of how much parents might be able to help their children with their homework appeared to relate to student achievement levels, the lower the level of students, the less expected from parents. Cathy taught honors biology and regular biology students; she had fewer concerns that students would not be able to do their homework without help. Some of David's students had special needs and others were multilingual learners. He mainly relied upon class time for students to study and in a few classes a special education teacher co-taught with him.

Students

Cathy was more likely than David to view aspects related to students as supports than barriers (**Table 4**). Also, it was clear throughout the PD program that when Cathy talked about teaching biology and her students' reactions to science lessons, she was trying to become more adaptive. When David talked about students, he seemed mainly concerned that they finish their work and connect finishing high school with getting a good job and/or going to college or vocational school. Both teachers reported that students' attitudes towards CISIP strategies supported their implementation of the PD. Cathy noted three student attributes that contributed to this supportive view: (a) regular

Table 4. Items that showed the greatest difference from Cathy and David's barriers and supports survey responses in parent and student categories.

Survey Item	*Cathy*	*David*	*Cathy – David*
Parents' ability to help my students with writing /discourse at home.	3	1	+2
My students' diverse language skills.	3	2	+1
My students' grade level background knowledge.	3	2	+1
My students' attendance.	5	3	+2
My students' ability to use metacognitive strategies.	4	2	+2
My students' attitudes towards the CISIP curriculum.	5	4	+1
My students' focus on academic oral discourse in small groups.	4	2	+2

attendance; (b) ability to use metacognitive prompts; and (c) focus on oral discourse in small groups. David, however, indicated that the latter two were minor barriers to his implementation of the PD strategies, while attendance was neither a support nor a barrier. Overall, Cathy reported a greater percentage of supports and fewer barriers to implementing the PD than David. Students' attitudes towards a different type of science instruction also may have been a barrier to David trying new strategies.

The teachers agreed that students' writing and discussion skills served as a minor barrier, but Cathy seemed more willing than David to tackle this issue, as she presented students with more opportunities to practice these skills. Both teachers commented how much students liked using notebooks and how they were better organized than before. While beliefs and identity are different constructs, revealing teachers' perceptions of supports and barriers to CISIP teaching helped explain why teachers were open or not to changing their instructional practices through the PD.

Discussion: Case study teachers' professional identities

To determine how institution and affinity identities were expressed through the teachers' beliefs about teaching and learning science I used a variety of data sources, including observations, interviews, and surveys. Analysis and construction of the case studies were strengthened with individual survey results and quantitative observation measures derived from field notes. The interpretative framework and associated methods have produced credible findings that may be transferable to other similar research contexts of teachers' use of PD in their science lessons.

Cathy's instruction demonstrated greater alignment with the PD model than David's, thus demonstrating a stronger affinity identity as a 'CISIP teacher' of diverse students. While both teachers could explain new instructional strategies that they learned, Cathy demonstrated greater use of the SCDC model than David, and her beliefs about teaching and learning were more aligned with the PD program's philosophy. For example, Cathy's project with her biology students in which they generated and justified their own questions, explored in-

formation about genetics, and made class presentations with various viewpoints demonstrated her ability to construct a SCDC with her students after years of relying on traditional direct instructional practices. However, she still restricted her inquiry-based teaching practices with those students she perceived as less able and motivated, which suggests some partial alignment with the institutional priorities of her school.

David's behaviors and discourse indicated that he was able to accommodate the PD into his teaching practice, but only in ways that did not disrupt his compliance to institutional priorities, thus demonstrating a stronger alignment with school culture in his institutional identity. David's affinity identity was not as strongly aligned with the PD, thus his position in the affinity group was more peripheral. In the framework of Lave and Wenger's legitimate peripheral participation, as she gained more experience, Cathy shifted her initial position as a new teacher in the affinity group towards a mentorship role in which she could speak with more authority and conviction about her new ways of teaching. In the following sections, selected evidence provides support for this interpretation of Cathy and David's teaching perspectives and actions through the lens of identity.

Stronger PD-aligned affinity identity

Cathy reported that CISIP was a vehicle for becoming 'a better teacher for her students'. Over time, Cathy's professional identity became more aligned with the CISIP norms and affinity-group teaching philosophy and instructional practices than the high-stakes testing, pressure-infused culture of her school where skill-and-drill activities were valued, and sometimes mandated, for rote learning. However, after a year of PD, there were still indicators that Cathy's teaching practices were in a transitional phase. She still mainly used guided inquiry lab activities but retooled them with metacognitive strategies and prompts to support student writing and processing of their ideas. Cathy also distinguished, and arguably discriminated, between college-prep and honors-tracked biology students and limited the degree of inquiry-based instruction she used with non-honors students. However, Cathy still adopted more of the PD than David did with lower-tracked students. Cathy's professional identity reflected aspects of both her institution

identity, specifically the culture and expectations of her school (e.g. ensuring students performed well on state tests), and her affinity identity a teacher who embraced and regularly tried to build a SCDC with her students.

Stronger institution identity

David enjoyed his interactions with CISIP as part of a school-based team, but ultimately, in his lessons he adapted the PD to fit his usual mode of teaching. David's institutional identity limited his emerging PD affinity identity; while he spoke knowledgeably about new ideas, David's perception of student capabilities as barriers and his school's tracking system co-constructed his institutional identity. David taught many students with identified special needs, a characteristic he viewed as a barrier to implementing inquiry-based lessons, but these students would have benefited from inquiry-based instruction the most (McGinnis and Kahn 2014). Because these students were more likely to fail compulsory state exams, David also felt administrative pressure that constrained the curriculum. Although he desired to change his practice, without perceiving freedom to change, David generally maintained his pre-PD institutional identity rather than adopting a more CISIP-aligned affinity identity. Despite his commitment to the PD, David accommodated only those instructional strategies that fit his paradigm of training students to follow directions and learn vocabulary to pass tests. Lasky (2005) also found similar findings about high school teachers' identity, agency, and professional risk-taking within the context of reform-based education stating that 'teachers struggled to remain openly vulnerable with their students and to create trusting learning environments in what they described as a more managerial profession with increased accountability pressures' (p. 899).

Teacher identity change

A key interview illustrated how Cathy adopted a new approach and how she felt that it fundamentally changed her teaching. She went from a direct instruction mode to facilitating rich discursive activities in her classroom. Cathy described moving away from her former

belief that when students talk that they are automatically off-task, to understanding that they need to talk and that they can be trusted to do so. Interestingly, in an interview with the PD program's external evaluator, she mentioned Cathy as an example of a teacher who found the PD engaging and thought about how to use new ideas with her students. This is another example of 'getting recognized' (Gee 2005) by an expert in the field as an adaptive adopter. While this is inherently intuitive for those who understand the affinity group context and its activities, this study sought to reveal numerous aspects that support and prevent teacher change in the context of educational reform for equity in science teaching in a minority-majority (Latinx) school.

Conclusions and implications

Research on teachers' instructional practices has indicated that 'we are long past the era of so-called teacher-proof curricula . . . what teachers do is not a formulaic following of rules, but nuanced, professional practice in which teachers constantly make important decisions and judgments in how they interact with their students to facilitate their learning' (Hewson 2007, 1180). More research is needed to better understand how teachers in the process of changing their teaching practices learn in a variety of educational and PD settings and how these experiences may affect their enacted instructional practices and professional identities. PD providers can benefit from broader conceptions of teaching and learning in science (e.g., use of scientific classroom discourse communities) as opposed to a science content-only approach. Also, from a research-to-practice perspective it is critical to understand if, and how, teachers develop new instructional knowledge and translate ideas from PD to their classrooms with their diverse students.

External factors like school culture can unwittingly block a teacher from adopting change. In particular pressures on teachers concerning low-performing students and state-mandated testing can hobble their efforts to embrace reformed-based, inclusive teaching practices. The more a school's culture and instructional paradigm differ from a standards-aligned PD model, presumably

the greater the challenge is for science teachers to make the leap

between traditional and reformed-based teaching practices. Thus, when recruiting teachers for PD, it also is critical to involve school- and district-level administrators to ensure that they are prepared to support teachers' efforts to try new ways of teaching and learning science. With most U.S. states' adoption or adaption of the NGSS with its focus on equity, educational systems must abandon didactic, test-prep approaches that emerged in the wake of NCLB and high-stakes testing policies (Nichols and Berliner 2007).

Internal factors, such as teachers' ideas about student learning, as well as their professional identities, have the potential to block or support implementing PD. In this study, a teacher who had high expectations for Latinx students' learning was more open to authentic science learning using inquiry-based instruction approaches. Ultimately, teachers must view all students as capable of learning science through experiential learning or they will insufficiently challenge students (Bryan, 2012). Both case study teachers viewed their lower-tracked students as less capable of inquiry and consequently avoided inquiry-based science practices and investigation with those students. This belief undermines equitable science education by diminishing the opportunity to learn (Carter & Welner 2013), especially for historically underrepresented students. Disenfranchising diverse students by limiting their learning in science maintains the status quo in higher education and continues underrepresentation in those majors and careers.

* * * * *

Box 1. School culture demanding compliance: 'We know this will be the best testing ever!' *A Vignette* Turning into Desert View High School's driveway I pass a large, digital sign that flashes a reminder for students to wear their identification badges. On the outside wall of the school is a yellow banner that labels the building 'A Performing Plus School.' Parking in a designated visitors' space, I walk to the roped-off entrance with a tripod and video camera where a school security guard stops me and I say, 'I'm from the university.' She relaxes her stern face and waves me towards the main office saying, 'That's fine, as long as you aren't taking pictures for the news.' As I walk away I hear her say into her walkie-talkie, 'White female, going to the office.' I sign in with the principal's secretary, who smiles and recognizes me from other visits and provides an official hall pass on a lanyard. I walk through a quiet courtyard to the science building, past the centrally located library and media center. Two teenagers who appear to be avoiding class are chatting at the drinking fountain as I make my way through the mostly-empty halls. Built into the hallway walls, banks of industrial-grade glass windows allow a view of every classroom; easy for administrators and security personnel to monitor what is happening inside without having to enter. Once settled inside Cathy's biology classroom I listen to the daily announcements as read by the assistant principal. Students stand for the pledge of allegiance, which is spoken slowly and deliberately, 'Please stand, and repeat with me: I pledge allegiance to the flag of the United States of America and to the republic for which it stands, one nation under God, indivisible, with liberty for all.' The now cheerful, but firm, voice of the AP explains that attendance is mandatory for the upcoming state reading test and that the school needs to have 100% attendance, so all sophomores need to be present on both testing days. They are offering breakfast for all test-takers at 7:00am before the testing. She sternly warns all other students, freshmen, and juniors and seniors who already passed the test not to arrive to campus prior to 11:15am, because, 'we want the testing to be the best we can have.' The voice admonishes teachers to read the revised class bell schedule every class period during the testing days, 'so that there are no questions or misunderstandings about the testing.' The disembodied voice continues to tell students to leave all their electronic devices at home as they will be taken away if they arrive with such prohibited items to the testing rooms. The Pollyanna voice presses on and concludes by stating, 'Be here, do your best and we know this will be the best testing ever!'

Disclosure No potential conflict of interest was reported by the author.

Funding This work was supported by the National Science Foundation DRL-03353469.

About the Author

Dr. Elizabeth Lewis is an associate professor of science education in the Department of Teaching, Learning, and Teacher Education at the University of Nebraska-Lincoln (UNL). She received her Ph.D. in curriculum and instruction in 2009 from Arizona State University. Dr. Lewis is a former geologist with her master's degree in geological sciences and taught high school Earth and space in Maine and Massachusetts. Dr. Lewis has been the principal investigator of several National Science Foundation (NSF) grants resulting in research on beginning science teachers and their reformed- based instructional practices, published in a 2020 volume entitled, *Linking Teacher Preparation Program Design and Implementation to Outcomes for Teachers and Students,* and a recent 2021 article in the *Journal of Research in Science Teaching*. She has also worked on other PI's NSF grants studying science teachers, including those undergoing professional development. These studies have been published in numerous science education research journals. She also investigates geoscience education issues, some of which have been published in the *Journal of Geoscience Education*.

References

[State] Department of Education. 2008. [State] Department of Education School Report Cards 2006-2007. Retrieved from [blinded to preserve anonymity].

Anyon, J. 1980. "Social Class and the Hidden Curriculum of Work." *Journal of Education* 162 (1): 67–92.

Avraamidou, L., Ed. 2016. *Studying Science Teacher Identity: Theoretical, Methodological and Empirical Explorations*. Rotterdam, The Netherlands: Sense Publishers.

Baker, D., Beard, R., Bueno-Watts, N., Lewis, E., Özdemir, G., Perkins, G., Uysal, S., Wong-Kavas, S., Yaşar-Purzer, S. 2008 Discourse in Inquiry Science Classrooms (DiISC): Reference Manual, Technical Report No. 001. The Communication in Science Inquiry Project (CISIP). (Tempe, AZ: Arizona State University)Authors in alphabetical order after lead author.).

Baker, D.R., Lewis, E.B., Purzer, S., Watts, N.B., Uysal, S., Wong, S., Beard, R., Lang, M. 2009. The Communication in Science Inquiry Project (CISIP): A project to enhance scientific literacy through the creation of science classroom discourse communities. International Journal of Environmental & Science Education, 4(3)259–274.

Barroso, A. and Brown, A., (2021). *Gender pay gap in U.S. held steady in 2020*. Accessed: 1 July 2021. https://www.pewresearch.org/fact-tank/2021/05/25/gender-pay-gap-facts/

Barton, A. C., E. Tan, and T. O'Neill. 2014. "Science Education in Urban Contexts" In N. Lederman and S. Abell. In *Handbook of Research in Science Education* (New York, NY: Routledge), 246–265.

Berliner, D. 2006. "Our Impoverished View of Educational Research." *Teachers College Record* 108 (6): 6. https://doi.org/10.1111/j.1467-9620.2006.00682.x

Brown, B. A. 2004. "Discursive Identity: Assimilation into the Culture of Science and Its Implications for Minority Students." *Journal of Research in Science Teaching* 41 (8): 810–834. https://doi.org/10.1002/tea.20228

Bryan, Lynn A. "Research on science teacher beliefs." In Second international handbook of science education, pp. 477–495. Springer, Dordrecht, 2012.

Carlone, H. B., C. M. Scott, and C. Lowder. 2014. "Becoming (Less) Scientific: A Longitudinal Study of Students' Identity Work from Elementary to Middle School Science." *Journal of Research in Science Teaching* 51 (7): 836– 869. https://doi.org/10.1002/tea.21150

Carter, P. L., and K. G. Welner, Eds. 2013. *Closing the Opportunity Gap: What America Must Do to Give Every Child an Even Chance*. New York, NY: Oxford University Press.

Carter, P., and L. Darling-Hammond. 2016. "Teaching Diverse Learners." In *Handbook of Research on Teaching*. *5th* ed., edited by D. Gitomer, and C. Bell, 593–638. Washington, D.C.: American Educational Research Association.

Carver-Thomas, D., and L. Darling-Hammond. 2017. *Teacher Turnover: Why It Matters and What We Can Do about It*. Palo Alto, CA: Learning Policy Institute.

Cochran-Smith, M., and S. L. Lytle. 2003. "Teacher Learning Communities." In *Encyclopedia of Education*, edited by J. W. Gutherie. New York: Macmillan.

Cuban, L. 1976. *Determinants of Curriculum Change and Stability, 1870-1970* (Washington, D.C.: National Institute of Education).

Cuban, L. 1992. "Curriculum Stability and Change." In *Handbook of Research on Curriculum*, edited by P. W. Jackson, 216–247. New York: MacMillan.

Erickson, F. 1986. "Qualitative Methods in Research on Teaching." In *Handbook of Research on Teaching*, edited by M. Wittrock, 119–161. *3rd* ed. New York: MacMillan.

Erikson, E. H. 1950. *Childhood and Society*. New York: Norton.

Fairbanks, C. M., G. G. Duffy, B. S. Faircloth, Y. He, B. Levin, J. Rohr, and C. Stein. 2010. "Beyond Knowledge: Exploring Why Some Teachers are More Thoughtfully Adaptive than Others." *Journal of Teacher Education* 61 (1– 2): 161–171. https://doi.org/10.1177/0022487109347874

Faltis, C., and G. Valdes. 2016. "Preparing Teachers for Teaching in and Advocating for Linguistically Diverse Classrooms: A *Vade Mecum* for Teacher Educators." In *Handbook of Research on Teaching*. *5th* ed., edited by D. Gitomer, and C. Bell, 549–592. New York, NY: American Educational Research Association.

Fraser-Abder, P., M. Atwater, and O. Lee. 2006. "Research in Urban Science Education: An Essential Journey." *Journal of Research in Science Teaching* 43 (7): 599–606. https://doi.org/10.1002/tea.20156

Gee, J. P. 2001. "Identity as an Analytic Lens for Educational Research". *Review of Research in Education* 25: 99–125.

Gee, J. P. 2005. *Introduction to Discourse Analysis (2nd Edition)*. London: Routledge.

Gee, J. P. 2004. Language in the Science Classroom: Academic Social Languages as the Heart of School-based Literacy. In *Establishing Scientific Classroom Discourse Communities: Multiple Voices of Teaching and Learning Research*, edited by R. K. Yerrick and W. Roth, 19–44. Mahwah, NJ: Lawrence Erlbaum Associates.

Hand, B. M., D. E. Alvermann, J. P. Gee, B. J. Guzzetti, S. P. Norris, L. M. Phillips, V. Prain, and L. D. Yore. 2003. "Message from the "Island Group": What Is Literacy in Science Literacy?" *Journal of Research in Science Teaching* 40 (7): 607–615. https://doi.org/10.1002/tea.10101

Hewson, P. W. 2007. "Teacher Professional Development in Science." In *Handbook of Research on Science Education*, edited by S. K. Abell and N. G. Lederman, 1177–1203. Mahwah, NJ: Lawrence Erlbaum Associates.

Ikoma, S. 2017. "Individual Excellence vs. Collaborative Culture: Sociology of Professions and Professionalization of Teaching in the US." In *International Handbook of Teacher Quality and Policy*, 38–51. New York, NY: Routledge.

James, W. 1890. *The Principles of Psychology*. New York: Henry Holt & Co.

Kafka, J. 2016. "In Search of a Grand Narrative: The Turbulent History of Teaching." In *Handbook of Research on Teaching*, edited by D. Gitomer, and C. Bell, 69–126, Washington, D.C.: American Educational Research Association.

Lasky, S. 2005. "A Sociocultural Approach to Understanding Teacher Identity, Agency and Professional Vulnerability in A Context of Secondary School Reform." *Teaching and Teacher Education* 21 (8): 899–916. https://doi.org/10.1016/j. tate.2005.06.003

Lave, J., and E. Wenger. 1991. *Situated Learning*. New York: Cambridge University Press.

Lead States, N. G. S. S. 2013. *Next Generation Science Standards: For States, by States*. Washington, D.C.: National Academies Press.

Lee, O., H. Quinn, and G. Valdés. 2013. "Science and Language for English Language Learners in Relation to Next Generation Science Standards and with Implications for Common Core State Standards for English Language Arts and Mathematics." *Educational Researcher* 42 (4): 223–233. https://doi.org/10.3102/0013189X13480524

Lewis, E.B., Baker, D., Bueno Watts, N., van der Hoeven Kraft, K. 2016 Science Teachers' Professional Growth and the Communication in Science Inquiry Project Professional Development: Recent Advances and Future Directions (Hauppauge, NY: Nova Science Publishers, Inc.) 1–57.

Lewis, E., Baker, D., Helding, B. 2015. Science teaching reform through professional development: Teachers' use of a scientific classroom discourse community model Science Education 99 896–931.

Loucks-Horsley, S., K. E. Stiles, S. Mundry, and P. W. Hewson, Eds. 2009. *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, CA: Corwin Press.

Luft, J. A., & Hewson, P. W. (2014). Research on teacher professional development programs in science. In Handbook of Research on Science Education, Volume II (pp. 903–924). Routledge.

McGinnis, J. R., and S. A. M. I. Kahn. 2014. "Special Needs and Talents in Science Learning." In *Handbook of Research on Science Education*, edited by S. Abell, and N. Lederman, 223–245. Vol. 2. New York, NY: Routledge.

Mead, G. H. 1934. *Mind, Self, and Society*. Chicago: University of Chicago Press.

Miles, M. B., and A. M. Huberman(1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Thousand Oaks, CA: Sage Publications.

Moje, E. B., K. M. Ciechanowski, K. Kramer, L. Ellis, R. Carrillo, and T. Collazo. 2004. "Working toward Third Space in Content Area Literacy: An Examination of Everyday Funds of Knowledge and Discourse." *Reading Research Quarterly*,39 (1): 38–70. https://doi.org/10.1598/RRQ.39.1.4

Moll, L. C., C. Amanti, D. Neff, and N. Gonzalez. 1992. "Funds of Knowledge for Teaching: Using a Qualitative Approach to Connect Homes and Classrooms." *Theory into Practice* 31 (2): 132–141. https://doi.org/10.1080/00405849209543534

Nasir, N. S., J. Scott, T. Trujillo, and L. Hernandez. 2016. "The Sociopolitical Context of Teaching." In *Handbook of Research on Teaching*. *5th* ed., edited by D. Gitmor, and C. Bell, 349–390. Washington, D.C.: American Educational Research Association.

National Research Council. 2000. *How People Learn*. Washington, D.C.: National Academies Press.

National Research Council (2005). *How students learn: History, mathematics and science in the classroom, a targeted report for teachers*. Washington, D.C.: National Academies Press.

Nichols, S. L., and D. C. Berliner. 2007. *Collateral Damage: How High-stakes Testing Corrupts America's Schools*, 02138. Cambridge, MA: Harvard Education Press.

Roeser, R. W., S. C. Peck, and N. S. Nasir(2006).Self and Identity Processes in School Motivation, Learning, and Achievement. in P. A. Alexander & P. H. Winne, *Handbook of educational psychology*. Lawrence Erlbaum Associates Publishers, 391–424.

Rushton, E. A., and M. J. Reiss (2020). "Middle and High School Science Teacher Identity Considered through the Lens of the Social Identity Approach: A Systematic Review of the Literature." *Studies in Science Education*, 57(2):1– 63.

Taylor, F. 1911. *The Principles of Scientific Management*. New York: Harper & Row.

Tschannen-Moran, M., and A. W. Hoy. 2001. "Teacher Efficacy: Capturing an Elusive Construct." *Teaching and Teacher Education* 17 (7): 783–805. https://doi.org/10.1016/S0742-051X(01)00036-1

van Driel, J. H., J. A. Meirink, K. Van Veen, and R. C. Zwart. 2012. "Current Trends and Missing Links in Studies on Teacher Professional Development in Science Education: A Review of Design Features and Quality of Research." *Studies in Science Education*, 48 (2) 129–160. https://doi.org/10.1080/03057267.2012.738020

Vygotsky, L. 1986. *Thought and Language*. Cambridge, Massachusetts: MIT Press.

Wallace, J., and J. Loughran. 2012. "Science Teacher Learning". In *Second International Handbook of Science Education*, edited by B. J. Fraser, K. Tobin, and C. J. McRobbie, 295–306. New York: Springer.

Wenger, E. 1998. *Communities of Practice: Learning, Meaning, and Identity*. New York: Cambridge University Press.

Yin, R. 1994. *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage Publications.