Mapping Epistemic Orientation towards Teaching Science with Classroom Instruction: A Longitudinal Professional Development Study

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Abstract

As part of a larger effort to understand the impact of professional development (PD) on teachers' thinking and practices, this research explores changes in epistemic orientation (and associated practices) of two cohorts of secondary science teachers as they were involved in a longitudinal PD. To measure epistemic orientation, Epistemic Orientation toward Teaching Science surveys were administered at three-time points and teachers' classrooms were observed. Findings suggest that change in epistemic orientation occurred for teachers who engaged in two years of PD, but that one year was not sufficient to engender such changes in epistemic orientation or instructional practice. These findings speak to the need for continuous, high-quality, longitudinal PD.

Purpose

Current reform efforts in science education focus on creating environments where students grapple with and negotiate their own understandings and explanations of scientific phenomena using disciplinary content and science practices knowledge (NGSS Lead States, 2013; NRC, 2012). For this reformed vision to become a reality, effective professional development (PD) is essential. With student-centered instruction as a primary focus of reform efforts, PD programs that generate shifts in teachers' attitudes, beliefs, and practices are critical (Desimone, 2011; Hand et al., 2018; Suh, 2016).

The problem that arises is that conventional PD often falls short of their goals and changes in beliefs, in part because they occur at one time point or over short time periods (Birman et al., 2000; Easton, 2008) and because they do not provide opportunities for teachers to engage in effective PD strategies such as enabling the collective participation of teachers; providing opportunities for collaboration; and use artifacts of practice (Southerland et al., 2016; Garet et al., 2001; Wilson, 2013). These 'one-shot' workshops offer minimal space for teachers to overturn existing attitudes, beliefs, or practices in ways that impact their instruction (Birman et al., 2000). In response, a growing body of research investigates the role of teacher learning through PD focused on collaborative design of curriculum (Coenders et al., 2010; Simmie, 2007). Through such design, teachers are exposed to, engage with, and actively shape new practices (Voogt et al., 2012), activities thought to be influential in teacher learning (Gomez et al., 2015). Research suggests that such learning is in part due to the development of a teachers' willingness to experiment with their commitment to targeted instructional approaches and beliefs about the influence of those instructional approaches (Voogt et al., 2016; Simmie, 2007). This work provides a space to explore how longitudinal collaborative PD impacts teachers' beliefs.

Theoretical Framework

Epistemological beliefs of science teaching and learning are broadly understood to include teachers' ideas about the nature of knowledge and about teaching and learning. These beliefs are core to practice and it is argued that PD should prioritize them as a precursor for change (Windschitl, 2002). Granger et al. (2018) discuss the recursive relationship of beliefs and practices in changing how science is taught in classrooms. Epistemological beliefs shape teachers' understanding and thus use of instructional practices that are emphasized in their classrooms (Buehl & Fives, 2009).

Epistemological orientation to science teaching arises from epistemological beliefs. This orientation, though similar, is thought to include a set of beliefs necessary for implementing science practices, beliefs long-acknowledged as fundamental in shaping teachers' practice (Southerland et al., 2016; Luft & Roehrig, 2007; Windschitl, 2002).

To better understand the impacts of longitudinal PD focused on collaborative design, this study explores the change in science teachers' epistemological orientations toward science teaching and their instructional practice across two years of sustained PD. **The research questions are: 1. What impact does longitudinal PD have on science teachers' epistemic orientations? 2. How do shifts in epistemic orientations translate to instructional practice?**

Methods

This mixed methods study employed paired-sample t-tests to examine Likert-scale epistemic orientation survey data collected from teachers involved in longitudinal PD centered on engaging teachers in opportunities for collaborative design while examining their instructional quality through use of rigor scoring rubrics.

Context and Participants

This research is a part of a larger study, focused on supporting teachers in fostering student sensemaking through productive science talk. It began in the summer of 2018 with 36-hours of PD structured to meet current recommendations for effective PD (Desimone, 2009; Wilson, 2013) and collaborative lesson design (Voogt et al., 2015). After the summer PD, teachers could choose to continue into the school year and engage in four cycles of collaborative design, each consisting of 3-hour sessions of lesson design, lesson enactment, and lesson analysis. During the design sessions, the four secondary science teacher of focus here (Table 1) worked with one another or the research team to develop or revise argumentation lessons. Teachers were then video recorded teaching the lesson with key instructional moments that supported or had potential to support student talk being clipped. Clips were collectively examined by the teachers during the analyze sessions and they revised their lessons based on this analysis and their teaching experiences. Each cycle focused on a specific theme that supported the development of teaching practices that foster student sensemaking. After the first year (Y1), the teachers were supported during a second year (Y2) to work collaboratively with the same teachers or researchers as in Y1 to revise, enact, and reflect upon lessons designed during Y1.

Data Sources

Two instruments were used to measure teachers' epistemic orientations and instructional quality. The Epistemic Orientation toward Teaching Science (EOTS) survey measures epistemic orientations and consists of 44 five-point Likert scale items categorized into four dimensions and 11 subdimension (see Table 2; (Park et al., 2018)). The Instructional Quality Assessment Science Observation Rubrics (IQA-SOR) was used to examine the level of instructional quality (i.e., rigor and talk found in different parts of a task) measured across four areas (see Table 3; (Tekkumru-Kisa et al., 2021)).

Data Collection

The EOTS was administered at three time points: prior to summer PD (pre-Y1), after the first year of in-school cycles (post-Y1), and after the second year of in-school cycles (post-Y2). Classroom video and audio was collected across the two years. We examine one lesson enacted in both years for each teacher. We chose this lesson because it was a lesson the teacher taught across the two years, because we felt it represented the clearest picture of their instructional changes based on initial examination, and because teachers talked about this lesson as representing their instructional shifts.

Analysis

EOTS analysis was conducted through use of a composite score (Park et al., 2018) and mean dimensional scores. Composite scores could reach a maximum of 15.36, and each dimensional score ranges from 1.0 to 5.0. Scores closer to the maximum indicate a more desirable epistemic orientation for implementing science practices in the classroom. Both composite and dimensional mean scores were used in paired sample t-tests for each survey administration. For instructional analysis, we used the four IQA-SOR rubrics. Three coders (IRR 80%), one of whom is the first author, watched recordings from each lesson to determine IQA-SOR scores and met to discuss and resolve any discrepancies in coding.

Results

Changes in Science Teachers' Epistemic Orientations

Table 4 displays the EOTS composite scores across time for all participants; these scores were initially high and remained high throughout the PD. The only significant difference in mean composite scores was seen between pre-Y1 and post-Y2, $t(3) = -3.30$, $p < 0.05$ (Table 5). There were no significant differences between mean scores for the four dimensions of the EOTS from pre-Y1 to post-Y1; however, for the Epistemic Alignment dimension, a significant difference between mean dimensional scores from pre-Y1 to post-Y2 was found, $t(3) = -6.57$, $p < 0.05$ (Table 6). A significant difference for the Student Ability dimension from pre-Y1 to post-Y2 also occurred, $t(3) = -3.22$, $p < 0.05$ (Table 7). As well, the Student Ability dimension showed a significant difference between mean dimensional scores from post-Y1 to post-Y2 surveys, $t(3) = -3.43$, $p < 0.05$ (Table 7). All significant changes in scores are in the positive direction.

Changes in Science Teachers' Classroom Instruction

Turning to the impact of changes in epistemic orientation in the classroom, from the significant changes noted above, we chose to focus on a deeper analysis of the Epistemic Alignment dimension, specifically, the How to Teach (EA-HT) sub-dimension for each teacher. The statements which make up this sub-dimension (See Table 8) directly align with observable instructional decisions seen in classroom enactment.

Jerry, Monica, and Danny increased the rigor of their instruction from Y1 to Y2 (Table 9). Though her score dropped, Kate still maintained high-quality instruction in her classroom and provided rigorous instruction both years.

Jerry increased rigor in his launch from a 3, "doing school", to a 4, where students are positioned as "doing science" with a phenomenon-based guiding question (Fig. 1). Jerry increased his whole class wrap-up from a 1, where an IRE pattern predominates with the teacher deciding on correctness, to a 4 where students are presenting their ideas and are positioned as the intellectual authority. Jerry's instruction went from "telling the correct answer" to orchestrating an explanation with student ideas. This shift in implementation is aligned with Jerry's epistemic orientation where his beliefs around incorrect responses and how explanations are constructed (Q9 EOTS) shifted.

Monica increased rigor in her whole class wrap-up from a 3 in Y1 to a 4 in Y2 (Fig. 2). Like Jerry, her students in Y2 were the intellectual authority with her as facilitator. This change aligned with belief shifts in how instruction should be built around problems and their solutions (Q4 EOTS) and beliefs about how students should be provided the opportunity to challenge each other's ideas (Q43 EOTS). During whole-class discussion, Monica facilitated students' presentations of their ideas, building space where students could ask questions and come to whole-class solutions together.

Danny increased rigor in his whole class discussion, moving from having no discussion in Y1 to having one in Y2 (Fig. 3). An interesting part of Danny's approach was in his elicitation of student ideas during the launch, and the shift to focus the conversation on what students already know about chemistry as well as about their life experiences. While there was no change in rigor launch scores from Y1 to Y2, students were contributing ideas in a more connected way in Y2. Danny's beliefs, while holding constant that a teacher should find out what students know at the beginning of the topic (Q39 EOTS) foregrounds student experiences more in Y2 than Y1.

Overall

These findings indicate that change in epistemic orientations occurred for teachers after two years of PD consisting of 36 hours of summer PD and two years of intensive in-school follow-up. Further, the data suggest that such PD and only one year of in-school follow-up is not sufficient to engender change in epistemic orientations or changes that manifest in decisions that produce rigor in classroom instruction. The high-quality nature of the PD is defined by its sustained focus on learning to foster productive science talk and intensive collaboration on lesson design and analysis between teachers as recommended by Darling-Hammond et al. (2017) and Desimone (2011). These features, when sustained over two years, supported teachers to shift their epistemic orientations in ways that align with desirable instruction of science content and practices (NGSS Lead States, 2013). The support provided teachers space for reflection that promoted further changes in their instruction to better engage students in sensemaking. During the first year of the PD, the analyze sessions during the in-school cycles allowed teachers to not only reflect on their own practice, but also that of their colleagues. Additional reflection was prompted by the inclusion of pre/post lesson interviews for each of the four designed lessons taught in Y1 and Y2, and by end-of-year interviews. These findings align with those in the literature that speak to change in epistemic beliefs promoted by reflection on teaching practices in the classroom (Adibelli & Bailey, 2017; Lunn Brownlee et al., 2017).

Scholarly Significance of the Study

The preliminary findings reported herein provide support for sustained PD, corroborated by changes in instructional quality, and provide evidence for specific PD features that support change in teachers' epistemological beliefs. Our findings show promising significant differences in composite EOTS scores, indicating development of desired epistemological orientations following PD that is of sufficient duration. They further suggest that continuous, high-quality longitudinal PD is key to change teachers' epistemological beliefs and practices. The longitudinal nature of the PD allowed time for recursive reinforcement between beliefs and practices to occur. PD which extends into and allows reflection on teachers' own practice is important for shifting instructional practice to one that embodies the vision of science teaching presented in current reform documents, suggesting that the 'one-shot' workshops favored by district and school administrators are insufficient for change.

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Tables and Figures

Table 1. Study Participant Demographics and Selected Lesson (all names are pseudonyms)

Participant	Years Teaching	Gender & Ethnicity	Class Observed	Lesson Selection	Lesson Description
Kate	21	White Non-Latine Female	Middle school Biology	Venezuelan Guppies	Exploring mechanisms of sexual and natural selection to determine coloration among guppy populations.
Jerry	3	White Non-Latine Male	Middle School Biology	Venezuelan Guppies	
Monica	8	White Non-Latine Female	Advanced Placement Biology	Cladogram Morphology	Analysis of morphological and DNA based data to create a cladogram.
Danny	5	White Non-Latine Male	Advanced Placement Chemistry (Y1) /Chemistry Honors (Y2)	Periodic Trends	Investigating periodic table trends and electron configuration.

Table 2. Dimensions of Epistemic Orientation from Park et al. (2018)

Dimensions *(4)*	**Sub-Dimensions *(11)***
Epistemic Nature of Knowledge (EN)	Knowledge: Revisable
	Science: Revisable

Epistemic Alignment (EA)	Empirical Evidence-Based Alignment How to Learn How to Teach Justification Source (Authority)
Classroom Authority (CA)	Locus of Control Role of Teacher
Student Ability (SA)	Ability to Learn

Table 3. IQA-SOR Rubric Overview (Tekkumru-Kisa et al., 2021)

Rigor Rubric	Phase of the Lesson
R1	Potential of the lesson (student facing materials and lesson plans)
R2	Launch/framing
R3	Implementation or enactment(s) of the task's work
R4	Student discussion at the task's close/wrap-up

Table 4. EOTS Composites and Mean Dimension Scores for Each Participant

Participant	Pre-PD Composite Score	Post-Y1 Composite Score	Post-Y2 Composite Score	Mean EA Score	Mean EN Score	Mean CA Score	Mean SA Score
Daniel	11.62	10.97	12.55	3.88	3.75	3.63	4.00
Jerry	12.96	11.99	13.08	4.33	4.04	3.46	4.67
Kate	10.50	11.89	11.49	3.96	4.04	3.42	3.17

Monica	11.35	12.02	12.65	3.93	4.42	3.67	3.67

Table 5. Paired T-Test EOTS Composite Scores

	Pre-Y1	*Post-Y2*
Mean	11.61	12.44
Variance	1.042	0.461
Observations	4	4
t Stat	-3.304	
P(T<=t) two-tail	0.051	

Table 6. Paired T-Test Epistemic Alignment Dimension (EOTS)

	Pre-Y1	*Post-Y2*
Mean	3.91	4.16
Variance	0.12	0.09
Observations	4	4
t Stat	-6.571	
P(T<=t) two-tail	0.014	

Table 7. Paired T-Tests Student Ability Dimension (EOTS)

	Post Y1	*Post-Y2*
Mean	3.56	4.38
Variance	0.22	0.35
Observations	4	4
t Stat	-3.43	
P(T<=t) two-tail	0.04	

	Pre-Y1	*Post-Y2*
Mean	3.69	4.38
Variance	0.89	0.35
Observations	4	4
t Stat	-3.22	
P(T<=t) two-tail	0.056	

Table 8. EOTS Epistemic Alignment Sub-dimension - How to Teach Survey Statement Items

Question Number	Survey Statement Item
Q4a	Instruction should be built around problems with correct answers.
Q9a	Teachers should not let students develop answers that may be incorrect when they can just explain the answers directly.

Q39	Teachers should find out what students know at the beginning of the topic.
Q43	Teachers should provide their students with opportunities to challenge each other about their ideas.

Table 9. IQA-SOR Scores for Year 1 and Year 2

Teacher	Lesson	R1	R2	R3	R4
Danny	Y1	4	3	3	NA
	Y2	4	3	3	3
Jerry	Y1	4	3	3	1
	Y2	4	4*	3	4*
Kate	Y1	4	5	5	5
	Y2	4	4**	4**	NA
Monica	Y1	3	3	3	3
	Y2	3	3	3	4*

NA = Not present
* = Increase, ** = Decrease

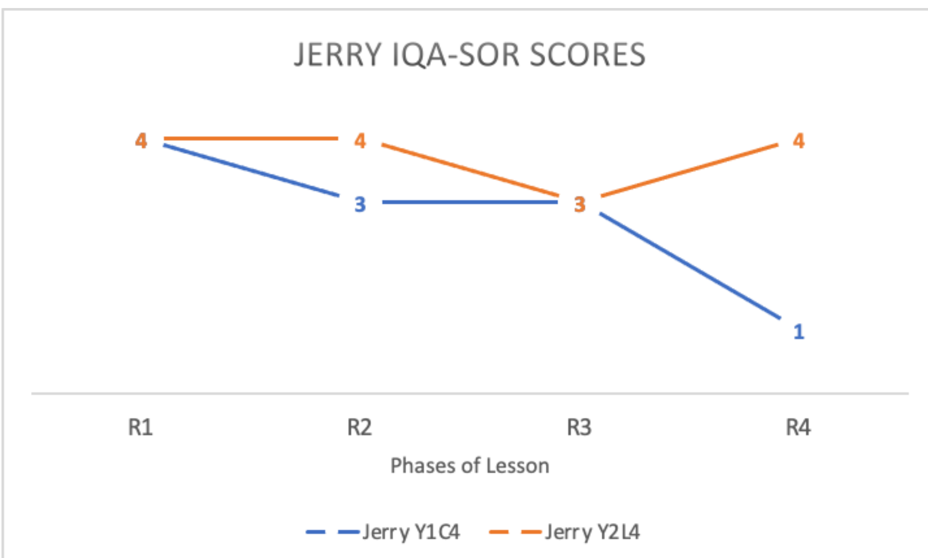

Figure 1. Jerry IQA-SOR score changes across Y1 and Y2.

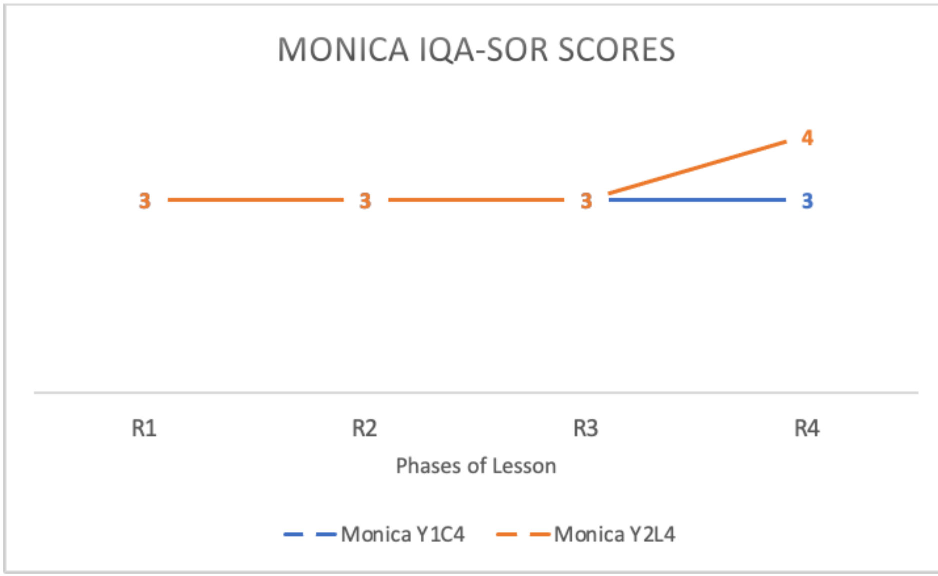

Figure 2. Monica IQA-SOR score changes across Y1 and Y2.

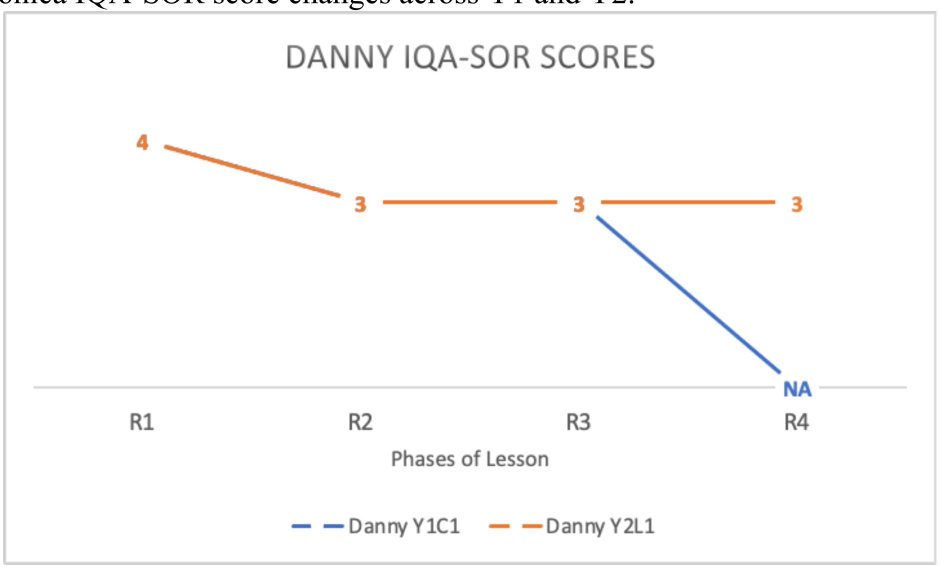

Figure 3. Danny IQA-SOR score changes across Y1 and Y2.

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