Exploration of Epistemic Orientation towards Teaching Science in a Longitudinal Professional Development Study

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Abstract

Current reform efforts in science education focus on creating environments where students grapple with and negotiate their own understandings and mechanistic explanations of scientific phenomena by using their knowledge of disciplinary content and science practices . In order to support this reformed vision, effective professional development (PD;) for science teachers is critical. If PD is to shape teachers' practice, teachers must experience a change in attitudes and beliefs . The research presented here explores the epistemic orientation of two secondary science teacher cohorts who were supported in a longitudinal professional development study. The epistemic orientation toward teaching science survey was administered at three time points for each cohort and paired sample t-tests were performed to analyze composite and dimensional scores. Our analysis revealed that change in epistemic orientation occurred for teachers who engaged in two years of supportive PD, but that one year of support was not sufficient to engender change in epistemic orientations. These findings further support the need for continuous, high-quality, longitudinal PD when the goal is a shift in science teachers' epistemological beliefs and teaching practices.

Subject/Problem

Current reform efforts in science education focus on creating environments where students grapple with and negotiate their own understandings and explanations of mechanistic scientific phenomena by using their knowledge of disciplinary content and science practices (NGSS Lead States, 2013; NRC, 2012). For this reformed vision to become a reality for all students, effective professional development (PD) for science teachers is essential. There is a growing body of research that investigates the role of teacher learning through PD focused on the collaborative design of curriculum (Coenders et al., 2010; Gomez et al., 2015; 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). Some research suggests that such learning is in part due to the development of a teacher's willingness to experiment with their instruction, their commitment to targeted instructional approach, and their beliefs about the influence of those instructional approaches (Voogt et al., 2016; Simmie, 2007).

With student-centered instruction as a primary focus of reform efforts, PD programs that generate shifts in teachers' beliefs and practices toward this disposition are critical (Hand et al., 2018; Suh, 2016). Desimone (2011) described that for PD to be successful, that is, for PD to shape teachers' practice, teachers must experience a change in attitudes and beliefs. Windschitl (2002) argues that PD should prioritize epistemological beliefs as a precursor for change. Granger et al. (2019) discuss the recursive relationship of beliefs and practices in changing how science is taught in classrooms. In sum, epistemological beliefs shape teachers' understanding and use of instructional practices that are emphasized in their classrooms (Buehl & Fives, 2009).

The problem that arises with PD is that many conventional offerings are enacted as fragmented workshops which tend to fall short of their desired goal, in part because they often occur at one time point or over short time periods (Birman et al., 2000; Easton, 2008). These 'one-shot' workshops offer minimal space for teachers to overturn their existing attitudes, beliefs, or practice in ways that impact their instruction (Birman et al., 2000). Even in non-traditional PD formats, such as those that longitudinally occur across multiple months or years, Porter and colleagues (2000) found variable consistency in quality across a teacher's involvement and concomitantly little impact on teacher instruction.

Epistemological beliefs in teaching and learning are often broadly defined in a general sense with little consensus on beliefs specific to instructional of a subject area, i.e. science (Park et al., 2018). Teachers' epistemological beliefs of science teaching and learning are broadly understood to include their ideas about the nature of knowledge, and their beliefs about science teaching and learning. Working from this broad understanding, teachers' epistemological orientation to science teaching is though to include a set of teacher's beliefs necessary for implementing science practices, beliefs that have been long-acknowledged as fundamental in shaping teachers' practice (Luft & Roehrig, 2007; Southerland et al., 2016; Windschitl, 2002).

Research Question

To better understand the impacts of a longitudinal PD, this study explores the change in science teachers' epistemological orientations toward science teaching across two years of sustained PD. **The research question that propels this work is: What impact does longitudinal PD have on science teachers' epistemic orientation?**

Design/Procedure

Methodology: This quantitative study employed paired-sample t-tests to examine Likert-scale survey data collected from teachers involved in a longitudinal PD over multiple time points.

Context: This research was conducted as a part of a larger NSF-funded study, focused on supporting teachers in fostering student sensemaking through productive science talk. The program 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 etl a., 2015). Teachers had the option to continue into the school year to engage in four cycles of collaborative design, each consisting of a session of lesson design, lesson enactment, and lesson analysis. During design sessions, each occurring over approximately 3 hours, teachers worked with one another or with the research team to develop or revise argumentation lessons focused on key science concepts. Teachers then taught the lesson in their classrooms. Each lesson was video recorded, key instructional moments that supported or had the potential to support student talk were identified and clipped from these recordings by the research team, these clips were collectively examined during analyze sessions, and teachers revised their lessons based on this analysis, each session lasting approximately 3 hours. Each iterative cycle focused on a specific theme that supported the development of teaching practices that foster student sensemaking. The PD (summer institute + in-school cycles of collaborative design) was offered to two cohorts of teachers (cohort 1 and 2) over two years with each cohort coming from a new district; both districts were located in the Southeastern US. Cohort 1 engaged in a second year of PD in which they were supported during the school year to work collaboratively with a project peer or the research team to revise the lessons designed in the first year of the PD, to design new lessons focused on productive science talk, and to collaboratively unpack each lesson after it was taught.

Participants: This paper reports on secondary science teachers that we followed from the two cohorts who engaged in the summer institutes as well as the in-school cycles of collaborative design. From the first cohort we focus on four teachers (Daniel, Jerry, Kate, and Monica) who permitted us to observe the four lessons they designed in the first year (Y1) of the PD and retaught in the second year of the PD (Y2) with the addition of lessons they collaboratively design with a peer or the research team in Y2. From the second cohort, we followed five teachers (Tina, Renee, Karly, Gloria, and Shelly) from the second iteration of the PD who also permitted us the same access to observing their lessons.

Instrumentation: The Epistemic Orientation toward Teaching Science (EOTS) Survey was selected as one of the research instruments in the larger project and it provides the data that is the focus of this paper (Park et al., 2018). The EOTS consists of 11 sub-dimensions, which come from the initial conceptual model of the EOTS, and constitute four dimensions: Epistemic Nature of Knowledge (EN), Epistemic Alignment (EA), Classroom Authority (CA), and Student Ability (SA), see table 1.The survey consists of 44 items that are rated on a five-point Likert scale (Strongly disagree: 1, Disagree: 2, Unsure: 3, Agree: 4, and Strongly Agree: 5). Park et al. (2018) created a composite score equation for the survey($0.625\times EN + 1.042\times EA + 0.763\times CA + 0.642\times SA$), which was used in this analysis.

Table 1. 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	Locus of Control Role of Teacher
Student Ability	Ability to Learn

Data Collection: The EOTS was administered to the first cohort of teachers at three different points: prior to the 2018 summer PD, after the first year of in-school cycles that occurred over the 2018/2019 school year, and after the second year of project support that occurred during the 2019/2020 academic year. The EOTS was administered to the second cohort of teachers at three different points: prior to the 2019 summer PD, after the 2019 summer PD, and after their year of in-schools cycles of collaborative design that occurred during the 2019/2020 school year. Teachers in the second cohort only engaged in two cycles of collaborative design due to the Covid-19 pandemic that occured in the latter half of the school year.

Findings and Analysis

Table 2 displays the mean composite scores (average of the three time points) for all participants (n=9); these scores are relatively high as they approach the maximum score of 15.36. The table also includes the mean scores for each dimension (average of the three time points), with a score range of a minimum of 1 to maximum of 5. The closer these scores are to the maximum the more desirable a teacher's epistemic orientation for implementing science practices in their classroom. These scores provide an overall sense of the epistemic orientations of each teacher across all EOTS survey administrations.

Table 2. Mean Composite and Mean Dimension Scores for Each Participant

Participant	Mean Composite Score	Mean EA Score	Mean EN Score	Mean CA Score	Mean SA Score
Daniel	11.71	3.88	3.75	3.63	4.00
Jerry	12.68	4.33	4.04	3.46	4.67
Kate	11.29	3.96	4.04	3.42	3.17
Monica	12.01	3.93	4.42	3.67	3.67
Karly	12.21	4.11	4.00	3.54	4.25
Gloria	13.67	4.33	4.75	4.25	4.58
Renee	13.59	4.63	4.75	3.75	4.58
Shelly	13.86	4.58	4.71	4.13	4.67
Tina	13.04	4.21	4.04	4.25	4.50

For cohort 1, paired sample t-tests were performed for each of the four dimensions as well as the composite scores for each survey administration. For the first cohort, there was no significant difference between mean composite scores from the pre-Y1 PD (before the 2018 summer PD) and post Y1 PD (2018/2019 in-school cycles) survey administrations, nor was there a significant difference between mean composite scores given at the end of Y1 and at the end of Y2 (2019/2021 in-school PD). However, there was a significant difference between mean composite scores between the pre-Y1 PD survey administration and that which followed the Y2 in-school PD, $t(3) = -3.30$, $p < 0.05$ (Table 3). There were no significant difference between mean scores for the four dimensions of the EOTS for pre-Y1 PD and post Y1 surveys for cohort 1. However, for the Epistemic Alignment dimension, a significant difference between mean dimensional scores for pre-Y1 and post Y2 surveys was found, $t(3) = -6.57$, $p < 0.05$ (Table 4). Likewise, for the Student Ability dimension there was a significant difference between mean dimensional scores for post Y1 and post Y2 surveys, $t(3) = -3.43$, $p < 0.05$. A significant difference for the Student Ability dimension between pre-Y1 and post Y2 surveys also occurred t, $t(3) = -3.22$, $p < 0.05$. All significant changes in scores are positive changes in the mean scores. For cohort 2, paired sample t-tests were performed for the composite scores and four dimensions, however no significant differences were found between mean composite scores or between mean scores for the dimensions.

Table 3. Cohort 1 Paired T-Test Composite Scores

	Pre PD	*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 4. Cohort 1 Paired T-Test Epistemic Alignment Dimension

	Pre PD	*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 5. Cohort 1 Paired T-Tests Student Ability Dimension

	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 PD	*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	

These findings support that the 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. The data suggest that one year of PD including 36 hours of summer PD and in-school follow-up is not supported as sufficient to engender change in epistemic orientations. The high quality nature of the PD is defined by its sustained focus on learning to foster productive science talk over time and the intensive collaboration on lesson design and analysis between teachers as recommended by Darling-Hammond et al. (2017). These features, when occurring 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 in both cohorts included space for reflection that promoted further changes in their instruction to better engage students in sensemaking. For the first year, the analyze sessions during the in-school cycles provided this space where teachers were able to not only reflect on their own practice but also that of their colleagues. Additionally, reflection was prompted by the inclusion of pre/post lesson interviews with the teachers for each of the four designed lessons taught in Y1 and Y2 of the PD, and by end-of-year interviews. Cohort 2, while able to engage in some reflection, did not complete the entire year of in-school cycles, having an abbreviated amount of PD along with limited reflection opportunities could have an effect on their EOTS survey scores for the post-in-school cycles. These findings align with those in the literature that speak to change in epistemic beliefs being promoted by reflection on teaching practices in the classroom (Adibelli & Bailey, 2017; Lunn Brownlee et al., 2017).

Contribution to the Teaching and Learning of Science

While a larger set of EOTS survey data from additional teachers is needed, these preliminary findings show promising significant differences in composite EOTS scores, indicating development of desired epistemological orientations with PD that is of sufficient duration. They further support the need for continuous, high-quality longitudinal PD as important for change in teachers' epistemological beliefs and practices. The longitudinal nature of the PD allowed time for recursive reinforcement between beliefs and practices to occur. Effective follow-up for teachers after PD is key for shifting teachers practice to one that embodies the vision of science teaching presented in the current reforms. Meaningful and substantial PD and follow-up that is more than the 'one-shot' workshop favored by district and school administrators is needed. The preliminary findings reported herein provide support for sustained PD, and provide evidence for PD features that support change in teachers' epistemological beliefs.

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