

RESEARCH REPORT

Effectiveness of an Inquiry Focused Professional Development: Secondary Mathematics and Science Teachers' Beliefs and Instruction

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Abstract:

Secondary (grades 6th-12th), mathematics and science teachers participated in a two-year inquiry-based professional development (PD) program focused on inquiry-based instruction. This study draws from surveys and classroom observations to assess potential changes in teacher beliefs (Teaching Philosophy, Openness to Change, Job Satisfaction, Professional Commitment, and Inquiry) and instructional practices using the electronic quality of inquiry protocol (EQUIP). Results of a one-way repeated-measures ANOVA found significant increases in participating teachers' Teaching Philosophy, Openness to Change, Confidence toward Inquiry, and Intentions toward Inquiry. Findings also indicate significant changes in teachers' instructional practice with teachers participating in the PD implementing higher levels of inquiry instruction in their classroom. Finally, a two-way repeated-measures ANOVA found statistically significant differences in participating teachers' Teaching Philosophy, Openness to Change, Confidence toward Inquiry, and Intentions toward Inquiry when evaluated with a comparison group of teachers. Overall, results indicate changes in teachers' beliefs and use of inquiry in their classroom due to their participation in the PD.

Keywords: Teacher professional development, inquiry instruction, mathematics education, science education, secondary education

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Initiatives in mathematics and science education – including the transition to new standards – call for teachers' use of reform-based instruction in the classroom (National Council of Teachers of Mathematics [NCTM], 1989; 2000; 2014; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; National Research Council [NRC], 2000; 2012; NGSS Lead States, 2013). Research supports these calls indicating improved learning when teachers are using reformed-based practices in both mathematics (Cain, 2002; Mac Iver & Mac Iver, 2009) and science classrooms (Furtak et al., 2012; Minner, Levy, & Century, 2010). Students in these settings also have increased interest and motivation for learning (Brown et al., 2013; Cichon & Ellis, 2003; Jiang & McComas, 2015).

With these initiatives and supporting research, there is a need to explore effective models of professional development (PD) for how to assist teachers in transitioning from a more traditional/direct instruction approach to a more reformed/inquiry approach in their classrooms. In this study, we highlight a model for PD with secondary mathematics and science teachers and examine its effectiveness for changing teachers' beliefs and classroom practice. Prior research exploring PD programs and beliefs related to inquiry-based instruction provide evidence to support how PD programs can lead to changes in teacher beliefs and their use of inquiry-based instruction (Yow & Lotter, 2014). However, many of these efforts do not consider these changes with respect to a comparison group of teachers, possibly accounting for changes that may evolve as teachers acquire more experience in the classroom. Additionally, while research notes the benefit of PD on transitioning beliefs related to reform- or inquiry-based instruction (Carney, 2016) and there is evidence to support teacher beliefs influencing teacher practice (Lloyd, 2002), this study examines the influence of the PD program on teachers' beliefs and classroom practice.

Literature Review

Inquiry Instruction

Inquiry instruction is a broad description of a variety of practices that support a student-centered method of instruction with a focus on conceptual understanding of content. The National Research Council (NRC, 1996) describes scientific inquiry as:

asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments (p. 105).

Calls for reformed instruction in both mathematics and science support the use of inquiry in the classroom (NCTM, 1989; 2000; 2014; NGSS Lead States, 2013). Marshall (2013) proposes a continuum of inquiry that ranges from highly teacher-structured to completely student-driven (with strong teacher support). This learner-centered perspective of engagement allows students

to actively construct their understanding of concepts by solving challenging tasks that require executive function, self-regulation, and meaningful discourse – skills that support deep conceptual learning – while being carefully scaffolded by the teacher (Bransford et al., 2000; NCTM, 2014; NRC, 2012). For example, teachers can develop inquiry-based instruction using existing tools like the 5E inquiry model – originally developed for science education (Bybee et al., 2006) or the 4E x 2 inquiry model – developed for both mathematics and science education (Marshall & Horton, 2009). In both instructional models, there are key phases of instruction: Engagement, Exploration, Explanation, Elaboration (5E) or Extension (4E x 2), and Evaluation. In both models, evaluation is iterative and occurs throughout the lesson to allow students to gain on-going feedback about their learning (see Marshall and Horton for a detailed explanation and comparison of the models). Research indicates a positive connection between inquiry-based instruction and the following: student achievement and understanding (Granger et al., 2012; Kang & Keinonen, 2018; Koksall & Berberoglu, 2012; Lazonder & Harmsen, 2016; Marshall & Horton, 2011; Minner et al., 2010), interest and motivation (Chen et al., 2014; Fielding-Wells et al., 2017), and attitudes toward science and mathematics (Kim, 2016; Riegle-Crumb et al., 2019). Knowing the benefit of inquiry instruction on a variety of student factors and measures, it is important to consider how to support teachers' use of this method of instruction in their classrooms.

Teacher Beliefs and Professional Development

Teacher beliefs – or “inferences made...about underlying states of expectancy (Rokeach, 1972, p. 2)” in teaching or learning – are part of an integrated cognitive system that are integral for enacting behavioral change (Rokeach, 1972). However, not all beliefs are equally important. Those that are most central to a person will be the most resistant to change, but if changed, will have the most profound repercussions on the rest of one's belief systems (Pajares, 1992; Richardson, 1996; Rokeach, 1972). Teachers' beliefs about: 1) themselves as professionals (professional identity), 2) inquiry as an effective pedagogical tool, 3) their perceived capabilities to design and implement inquiry-based instruction, and 4) carrying out inquiry in their future classrooms are known to influence teacher practice (e.g., Canrinus, et al., 2012; Cross, 2009; Hofer & Pintrich, 2004) and are germane to this study. Beliefs and experiences are interwoven (Raths, 2001), and teachers have a wealth of experiences both as a student and as a teacher that influence their beliefs (Lortie, 1975). Thus, teacher beliefs are an important but complex topic to research.

Creating dissonance between teachers' beliefs, practice, knowledge, and experiences is one way that literature recommends creating a space to enact teacher change (Woolfolk et al., 2009). However, even this idea can be complex as too much dissonance may lead to teachers' rejecting changes (Timperley & Alton-Lee, 2008). Drawing on a large body of literature related to teacher professional development is helpful for designing programs that effectively facilitate

teacher change. For example, research repeatedly cites the importance of professional development being content focused (Desimone, 2009; Taylor et al., 2017). Meaning that mathematics and science educators should be experiencing discipline specific PD rather than general PD, which is often the case with district and school provided PD. In fact, Moyer-Pakenham et al. (2010) noted that PD for mathematics and science teachers often only included a few measures assessing the effectiveness of PD activities and do not connect back to teachers' classrooms. Current literature focused on PD and teachers' use of reform- or inquiry-based instruction also highlights the importance of job-embedded experiences in order to transition beliefs to changes in practice (Shirrell et al., 2019). This focus aligns with other literature noting the positive effect that school-based initiatives, such as a professional learning community, can have on teacher change (Tam, 2015).

Based on the work of Desimone (2009) and Darling-Hammond and colleagues (2017), there are seven core features of PD that lead to subsequent change. Each of the seven features are supported by research as being effective, and thus, utilized in the design and evaluation of the PD described in this study. Table 1 provides an overview of the seven features along with supporting research citations.

Table 1.

Features of Effective PD

PD Feature	Brief Description	Related Research
Content focused	PD is discipline specific and include opportunities to explore curricula, examine student work, work on or teach lessons, and engage in strategies that are specific to the content of focus.	Gallagher et al. (2017); Johnson & Fargo, (2014)
Active learning	PD involves teachers being active participants in the learning process, which embodies the inquiry approach to learning that is often the focus of current PD. This feature also attends to literature on adult learning (e.g., Knowles, 1990; Trotter, 2006).	Allen et al. (2011); Gallagher et al. (2014)
Collaboration	PD includes teachers collaborating with one another or supporting personnel, such as coaches, and involve authentic experiences (in the school setting, with activities that related directly to the teachers' classroom and practice). These collaborations could be one-on-one meetings or be small groups and could include teachers reflecting, planning, engaging in activities, and solving problems.	Allen et al. (2015); Buczynski & Hansen (2010)
Models and modeling	PD provides models of the specific instructional practices/curriculum that are the topic of focus. These models can be included in a variety of formats such as case studies, model lessons, and student work.	Doppelt et al. (2009); Greenleaf et al. (2011)

Coaching and expert support	PD includes some type of coaching or expert support, which could include other teachers, content experts, instructional coaches, or university faculty. This support could be included as part of workshop activities, meetings at the school to observe and reflect, or virtual meetings such as videos shared and online discussions.	Kleickmann et al. (2016); Meissel et al. (2016)
Feedback and reflection	PD includes opportunities for feedback and reflection, “often employed during mentoring and coaching” (Darling-Hammond et al., 2017, p. 14).	Kutaka et al. (2017); Landry et al. (2009)
Duration	PD is on-going, multiple activities over time, rather than being a one-time activity/workshop.	Meyers et al. (2016); Polly et al. (2015)

The purpose of this study is to examine how secondary mathematics and science teachers’ beliefs and practice changed through their participation in a 2-year PD program. The research questions guiding this study are:

1. Are there changes in participating secondary mathematics and science teachers’ beliefs (teaching philosophy, job satisfaction, openness to change, and professional commitment) from the beginning to the end of the PD?
2. Are there differences in beliefs between the participating and comparison group of teachers?
3. Are there changes in participating secondary mathematics and science teachers’ beliefs toward, confidence in, and intentions to use inquiry from the beginning to the end of the PD?
4. Are there changes in teachers’ beliefs toward, confidence in, and intentions to use inquiry between the participating and comparison group of teachers?
5. Are there changes in participating secondary mathematics and science teachers’ level of inquiry instruction in their classroom?

Methods

Professional Development Model

The professional development was designed to highlight key features that research noted to be effective in changing teacher practice and affect student outcomes. Table 2 provides an overview of how features of the PD implemented over the two years aligned with features of effective PD outlined in the research.

Table 2.

Alignment of PD to Research-Based Practices

PD Feature	Alignment
Content focused	The PD program was designed specifically for mathematics and science teachers at the secondary level with instructional coaches and facilitators who had experience teaching mathematics and science at the secondary level. Instructional practices modeled were specific to mathematics and science education, and were research-based.
Active learning	Each activity during the academic year and summer involved active learning. For example, all teachers actively observed model lessons. After evaluation and discourse about the model lessons, teachers designed their own inquiry-based lessons, presented lesson ideas in workshop form to coaches and peers, received feedback, made revisions, and implemented lessons in the classroom where they were observed and formally evaluated using the observation protocol. Evaluation scores were then provided to the teachers so they could decide on goals they wanted to work on during the year (job-embedded). During the summer institutes, teachers learned about new strategies through experiential activities, designed problem- or project-based units, presented ideas, and received extensive feedback.
Collaboration	Teachers were intentionally placed in teams based on the district in which they worked to allow for collaboration at their school sites (job-embedded). Additionally, teachers were put into teams during the summer institute and worked together to create/modify lessons and units of instruction for the subsequent academic year (job-embedded).
Models and modeling	While model inquiry-based lessons were conducted during PD events, model lessons were also implemented in the teachers' classrooms with their students (job-embedded).
Coaching and expert support	An instructional coach partnered with groups of teachers to provide them continual coaching and support. This support often occurred at the teachers' location (job embedded), but also took the form of emails, phone calls, and team meetings during PD events.
Feedback and reflection	Teachers were provided feedback through a variety of data sources: during coaching sessions with master teachers, with observational data collected throughout the two years using the inquiry instruction research protocol, through teacher interviews and surveys, and through professional learning community discourse. Reflection occurred throughout the study using the aforementioned data sources.
Duration	This program was designed to be two-years in length and included activities throughout the academic year and a week-long intensive summer session each year.

Research Design

The purpose of the study was to examine the impact of a research-based professional development program (see Table 2) on participating teachers' beliefs in comparison with a group of teachers who did not participate in the PD. Aligned with this purpose, a repeated measure quasi-experimental survey research design was used. In addition, the study explored the impact the PD had on participating teachers' instruction. Aligned with this purpose, a nonexperimental repeated measure research design with an observational protocol was used.

Participants

There were two primary sources of data for Year 1 and Year 2 of the project including mathematics and science, middle and high school teachers (participating and comparison). It is important to note that during Year 1 of the project, some teachers opted out of participating after beginning project activities and were replaced by other teachers within the same district. This attrition left a sample size of 17 teachers who had completed a pre-, mid-, and post-administration of the survey. Participant selection was dictated by letters of collaboration from school districts agreeing to partner on PD activities as part of a grant-funded project. While some teachers within these districts chose to join the PD program, some were assigned to participate in the PD by their administrators. Additional comparison data were collected from a group of mathematics and science teachers at middle and high schools in adjacent districts in the state, sample size of 14 (with pre and post data). Demographic information for the participating and comparison group of teachers is provided in Table 3 and is representative of the teacher population within the districts.

Table 3.

Demographic Information for Participating and Comparison Groups of Teachers

	Race				Subject Taught		Grade Level Taught		Highest Level of Education			Mean YearsExp.
	F	Cau.	Asian	Other	M	S	6 th -8 th	9 th -12 th	BS	MS	PhD/EDD	
P	14	17	0	0	6	11	9	8	8	8	0%	7.2
C	6	12	1	1	3	11	3	11	7%	6	1	8.8

Note. P = participating; C = comparison; F = Female; Cau. = Caucasian; M = mathematics; S = science

Data Collection

Primary sources of data included teacher surveys and teacher observations. A combination of these sources of data provided information on the impact of the program on teacher outcomes. Several steps were taken to ensure the reliability and validity of data collected. The teacher survey was developed using existing instruments with existing reliability and validity information available (Meyer et al., 1993; Starr et al., 2006; Stearns et al., 2014; Vannetta & Nancy, 2004). Reliability scores using Cohen's d was also calculated for each factor.

Professional identity is an umbrella term for one's personal evaluations of self within a profession that can be comprised by the following factors: (1) Teaching Philosophy – 0.82, (2) Openness to Change – 0.73, (3) Job Satisfaction – 0.72, and (4) Professional Commitment – 0.86. Teaching Philosophy and Openness to Change both drew from the Teacher Attribute Survey (TAS; Vannetta & Nancy, 2004). The Teaching Philosophy scale “measured teacher support of a teacher-centered or student-centered instructional environment”, while the Openness to Change

construct measured teachers' "comfort and excitement when trying new methods of instruction as well as willingness to take risks and make mistakes" (Vannetta & Nancy, 2004, p. 255). Job Satisfaction drew from Stearns, Mickelson, and Moller's (2014) study exploring the construct, which included three items such as "I really enjoy my present teaching job." Occupational Commitment drew from Meyer and colleagues (1993) work, focusing on affective professional commitment with six items such as "Teaching is important to my self-image" and "I dislike being a teacher." It is important to note that Meyer's et al. (1993) was specific to the field of nursing; however, Canrinus et al. (2012) validated the items for the construct specific to the teaching profession.

Teacher's beliefs about inquiry instruction, perceived competence in designing and implementing inquiry-based instruction (confidence), and intention to use inquiry-based practices in their classroom were measured using a modified version of the measures created and implemented by Forbes and Zint (2011). Participants completed 7 items within each measure that were mathematics or science-specific based on their content-area focus. Each measure featured the same seven inquiry-based practices – e.g., "Ask questions and make predictions about [mathematical or scientific] concepts." -- but had a different question for the participant to consider. To assess participants' beliefs about inquiry, for example, the leading question was "When I am teaching [mathematics or science], I should design instruction that requires my students to..." followed by the seven practices and a 7-point Likert scale ranging from "strongly disagree" to "strongly agree". The factors and corresponding reliability scores using Cohen's α are as follows (1) Beliefs toward Inquiry – 0.92, (2) Confidence toward Inquiry – 0.93, and (3) Intentions toward Inquiry – 0.95.

The EQUIP observational protocol was used measure inquiry-based instruction of mathematics and science teachers (Marshall et al., 2008). The factors and corresponding reliability scores for the EQUIP observational instrument are as follows (1) Instructional – 0.94, (2) Discourse – 0.94, (3) Assessment – 0.89, and (4) Curriculum – 0.88. The Instructional factor included five items that relate to the type of strategies being used, sequence of instruction, role of the teacher and student and knowledge acquisition. The Discourse factor included five items that related to the level, complexity, and ecology of questions, communication pattern, and classroom interactions. The Assessment factor included five items including prior knowledge, conceptual development, student reflection, assessment type and the role of assessment. Finally, the Curriculum factor included four items related to content depth, learner centrality, integration of content and investigation, and organization and recording information. The scale on the instrument was 0 (not observed) to 4 (exemplary inquiry).

To ensure consistency in how the observational protocol was administered, every classroom observer was trained on the instrument. This training began by watching informational videos on the Inquiry In Motion website (iim.sites.clemson.edu) followed by watching classroom

videos and scoring these videos using the EQUIP protocol. The website provided scores so the raters could compare their rating with the “key” scores on the website. After completing these activities, the rater team met to discuss the EQUIP protocol in detail and go through another series of watching videos as a team and scoring teachers’ use of inquiry using the EQUIP protocol. These meetings included discussions that assisted in clarifying and eventually reaching consensus on components of the protocol. Further, inter-rater assessments occurred during the first implementation of the EQUIP protocol with a pair of observers collecting data on the same lesson. The second implementation involved one member of the research team accompanying two of the raters to verify consistency in scoring. Subsequent rounds of scoring were done independently since the raters had extensive experience with the instrument.

Data Analysis

For the participating teachers, the beliefs survey was implemented three times over the course of the two years: beginning of the spring semester in year 1 (pre-assessment), at the conclusion of the summer institute in year 1 (mid-assessment), and at the conclusion of the summer institute in year 2 (post-assessment). For the comparison group of teachers, the beliefs survey was implemented twice: at the beginning of the spring semester in year 1 (pre-assessment) and at the end of year 2 (post-assessment). To compare differences between the three time intervals (pre, mid, and post) for the participating teachers, a one-way repeated-measures ANOVA was conducted. To compare potential differences in means between the participating and comparison group of teachers, a two-way repeated-measures ANOVA was conducted. In addition, a Wilcoxon signed-rank test was performed to determine if differences existed between the pre- and post-assessment for the comparison group of teachers. Random imputation was conducted to address missing data.

The EQUIP protocol was also implemented four times during the two-year PD: at the end of the fall semester in year 1 (pre-observation), at the end of the spring semester in year 1 (mid1-observation), at the end of the subsequent fall semester in year 2 (mid2-observation), and at the end of the spring semester of year 2 (post-observation). Although a one-way repeated ANOVA would have been ideal for determining if differences existed between administrations of the protocol, a Wilcoxon signed-rank test was conducted instead because of the small sample size due to teacher attrition. To better understand potential differences in the program a Wilcoxon signed-rank test was run for the following (1) pre to post (N=14) and (2) mid2 to post (N=27).

Results

Research Question 1

Results of the one-way repeated-measures ANOVA assessing changes in teacher beliefs, pre-, mid-, and post-survey are reported in Table 4 for each of the four factors explored, including: (1) teaching philosophy as it relates to teachers' beliefs about a teacher- versus a student-centered classroom (Teaching Philosophy); (2) Job Satisfaction; (3) Openness to Change; and (4) Professional Commitment.

Results indicated that there was a significant change in teachers' Teaching Philosophy, $F(1, 32) = 14.842, p = 0.000, \eta^2 = 0.200$, and Openness to Change, $F(1, 32) = 4.565, p = 0.018, \eta^2 = 0.059$. The Mauchly's test for sphericity for Teaching Philosophy and Openness to Change was met ($W = 0.767, p = 0.136$; $W = 0.914, p = 0.510$ respectively) so the Huynh and Feldt correction was not used. A post hoc Bonferroni test for Teaching Philosophy showed that the pre- and mid-assessment differed significantly at $p = 0.002$ as well as the pre- and post-assessment at $p = 0.002$. A post hoc Bonferroni test for Openness to Change showed a marginally significant difference between the mid- and post-assessment at $p = 0.090$ as well as a statistically significant difference between the pre- and post-assessment at $p = 0.040$. Although the Job Satisfaction and Professional Commitment constructs were not statistically significant, it is worth noting that the means for these factors trended upwards over the course of the two years.

Table 4.

Results for ANOVA (Pre-Mid-Post) – Participating Teachers

Teacher Belief Factors	Pre M (SE)	Mid M (SE)	Post M (SE)	F
Teaching Philosophy ^a	4.17(0.16)	4.76(0.14)	4.76(0.12)	14.84***
Job Satisfaction ^b	4.27(0.17)	4.45(0.13)	4.51(0.15)	0.94
Openness to Change ^a	4.64(0.18)	4.75(0.13)	5.00(0.14)	4.57*
Professional Commitment ^c	6.20(0.18)	6.31(0.15)	6.25(0.17)	0.67

Note: † $p < 0.10$ * $p < 0.05$ ** $p < 0.01$

^a – Scale of 1-6, ^b – Scale of 1-5, ^c – Scale of 1-7

Research Question 2

A Wilcoxon signed-rank test indicated there were no differences for the comparison group of teachers from pre- to post-survey. In fact, for three of the four factors, there was a declining trend in the mean from the baseline to post survey for this group of teachers (See Table 5).

Table 5.

Results of Wilcoxon signed-rank test: Comparison Teachers, Pre – and Post-Survey

Teacher Belief Factors	Pre Survey	Post Survey	<i>p-value</i>
	<i>M (SE)</i>	<i>M (SE)</i>	
Teaching Philosophy ^a	3.66(0.25)	3.71(0.20)	0.681
Job Satisfaction ^b	4.17(0.19)	4.02(0.21)	0.476
Openness to Change ^a	4.44(0.19)	4.33(0.21)	0.421
Professional Commitment ^c	5.90(0.26)	5.89(0.27)	1.000

^a – Scale of 1-6, ^b – Scale of 1-5, ^c – Scale of 1-7

Finally, a two-way repeated-measures ANOVA was conducted pre- to post-survey to determine if differences existed for beliefs measured between groups (participant and comparison). Mauchly's test for sphericity is only applied with more than two levels. Since there are only two levels for our ANOVA, Levene's test for equal variance was conducted. This assumption was not violated for any of the variables, allowing us to proceed with the analysis. Results of the ANOVA indicated a significant interaction effect between teacher groups and the time interval for Teaching Philosophy, $F(1, 29) = 10.58$, $p = 0.004$, $\eta^2 = 0.044$. A follow up independent samples t-test found a significant difference between the post-survey responses with the participating teachers reporting a higher mean ($M = 4.76$) than the comparison group of teachers ($M = 3.67$). Results of the ANOVA also indicated a marginally significant interaction effect for Job Satisfaction, $F(1, 29) = 3.14$, $p = 0.087$, $\eta^2 = 0.022$. A follow up independent samples t-test found a significant difference between the post-survey responses with the participating teachers reporting a higher mean ($M = 4.51$) than the comparison group of teachers ($M = 4.02$). Openness to Change also had a significant interaction effect when conducting a two-way repeated-measures ANOVA, $F(1, 29) = 4.88$, $p = 0.035$, $\eta^2 = 0.030$. The follow up independent samples t-test found a significant difference between the post-survey responses with the participating teachers reporting a higher mean ($M = 5.00$) than the comparison group of teachers ($M = 4.33$). Professional Commitment was not significant when conducting a two-way repeated-measures ANOVA, $F(1, 29) = 0.15$, $p = 0.703$, $\eta^2 = 0.000$. Table 6 provides a summary of results for the independent samples t-tests and Figure 1 provides a visual representation of changes pre- to post-survey for the participating and comparison groups of teachers.

Table 6.

Independent Samples T-test for Post-survey between Groups of Teachers

Factor	Part. M(SD)	Comp. M(SD)	t	p-value	d
Teaching Philosophy ^a	4.76(.50)	3.67(.72)	4.987	0.000***	1.79
Job Satisfaction ^b	4.51(.61)	4.02(0.78)	1.945	0.062†	0.71
Openness to Change ^a	5.00(.58)	4.33(0.78)	2.753	0.010**	0.99

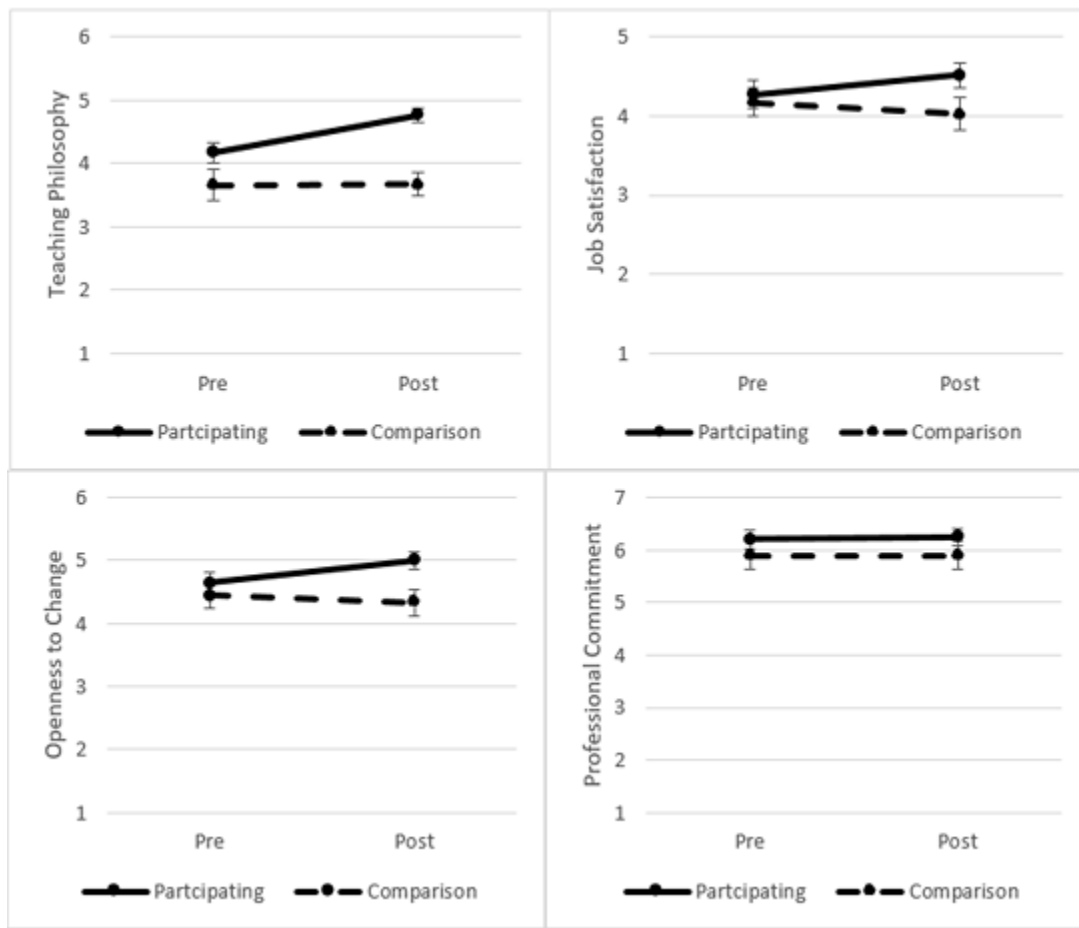
Note: † $p < 0.10$ ** $p < 0.01$ *** $p < 0.001$ ^a – Scale of 1-6, ^b – Scale of 1-5

Figure 1. Change in Beliefs Pre- to Post-Survey for Participating and Comparison Groups of Teachers

Research Question 3

The researchers asked participants to respond to a series of questions designed to assess their beliefs about, confidence in their abilities to design, and intentions for implementing instruction that is inquiry based. Results of the one-way repeated-measures ANOVA assessing changes in teacher beliefs, pre-, mid-, and post-survey are reported in Table 7 for each of the three

factors explored, including: (1) Beliefs toward Inquiry, (2) Confidence toward Inquiry, and (3) Intentions toward Inquiry.

Results indicated there was not a significant change in teachers' Beliefs toward Inquiry, $F(1, 32) = 1.480$, $p = 0.243$, $\eta^2 = 0.031$. However, it is worth noting that the mean for this factor trended upwards over the course of the two years. A significant change was found in teachers' Confidence toward Inquiry, $F(1, 32) = 15.546$, $p = 0.000$, $\eta^2 = 0.161$, and Intentions toward Inquiry, $F(1, 32) = 27.994$, $p = 0.000$, $\eta^2 = 0.311$. The Mauchly's test for sphericity for Confidence toward Inquiry was not violated ($W = 0.809$, $p = 0.205$); however this assumption was violated for Intentions toward Inquiry ($W = 0.527$, $p = 0.008$), so the more conservative Greenhouse-Geisser correction was used. This correction still indicated a significant change in teachers' Intentions toward Inquiry, $p = 0.000$. A post hoc Bonferroni test for Confidence toward Inquiry showed that the mid- and post-assessment differed significantly at $p = 0.006$ as well as the pre- and post-assessment at $p = 0.000$. A post hoc Bonferroni test for Intentions toward Inquiry showed that the pre- and mid-assessment differed significantly at $p = 0.001$, mid- and post-assessment differed significantly at $p = 0.013$, and the pre- and post-assessment differed significantly at $p = 0.000$.

Table 7.

Results for ANOVA (Pre-Mid-Post) – Participating Teachers

Teacher Belief Factors	Pre <i>M (SE)</i>	Mid <i>M (SE)</i>	Post <i>M (SE)</i>	F
Beliefs toward Inquiry	6.24(0.17)	6.25(0.17)	6.49(0.13)	1.48
Confidence toward Inquiry	4.82(0.24)	5.11(0.21)	5.74(0.21)	15.55***
Intentions toward Inquiry	5.00(0.27)	5.97(0.18)	6.32(0.15)	27.994***

Note: *** $p < 0.001$

Scales: (Strongly Disagree; Not at all confident; Very unlikely) – 7 (Strongly Agree; Completely confident; Completely likely)

Research Question 4

A Wilcoxon signed-rank test indicated there were no differences for the comparison group of teachers from pre- to post-survey. In fact, there was a declining trend in the mean for Intentions toward Inquiry from the pre- to post-survey for this group of teachers (See Table 8).

Table 8.

Results of Wilcoxon signed-rank test: Comparison Teachers, Pre – and Post-Survey

Teacher Belief Factors	Pre Survey	Post Survey	<i>p-value</i>
	<i>M (SE)</i>	<i>M (SE)</i>	
Beliefs toward Inquiry	6.07(0.22)	6.14(0.22)	0.753
Confidence toward Inquiry	5.34(0.22)	5.41(0.24)	0.779
Intentions toward Inquiry	5.67(0.26)	5.13(0.28)	0.209

Scales: (Strongly Disagree; Not at all confident; Very unlikely) – 7 (Strongly Agree; Completely confident; Completely likely)

Finally, a two-way repeated-measures ANOVA was conducted pre- to post-survey to determine if differences existed for beliefs measured between groups (participant and comparison). Levene's test for equal variance was conducted. This assumption was not violated for any of the variables, allowing us to proceed with the analysis. Results of the ANOVA indicated there was not a significant main effect for Beliefs toward Inquiry, $F(1, 29) = 9.19$, $p = 0.297$, $\eta^2 = 0.012$. However, a significant interaction effect for Confidence toward Inquiry was found, $F(1, 29) = 12.27$, $p = 0.002$, $\eta^2 = 0.072$. A follow up independent samples t-test did not find a significant difference between the post-survey responses between the participating and comparison group of teachers. Finally, a significant interaction effect was found for Intentions toward Inquiry, $F(1, 29) = 20.09$, $p = 0.000$, $\eta^2 = 0.200$. A follow up independent samples t-test found a significant difference between the post-survey responses with the participating teachers reporting a higher mean ($M = 6.32$) than the comparison group of teachers ($M = 5.13$). Table 9 provides a summary of results for the independent samples t-tests and Figure 1 provides a visual representation of changes pre- to post-survey for the participating and comparison groups of teachers.

Table 9.

Independent Samples T-test for Confidence and Intentions toward Inquiry, Post-survey between Groups of Teachers

Factor	Part. <i>M(SD)</i>	Comp. <i>M(SD)</i>	<i>t</i>	<i>p-value</i>	<i>d</i>
Confidence toward Inquiry	5.74(.86)	5.29(0.94)	1.243	0.224	0.50
Intentions toward Inquiry	6.32(.63)	5.13(1.05)	2.753	0.001**	1.42

Note: ** $p < 0.01$

Scales: (Strongly Disagree; Not at all confident; Very unlikely) – 7 (Strongly Agree; Completely confident; Completely likely)

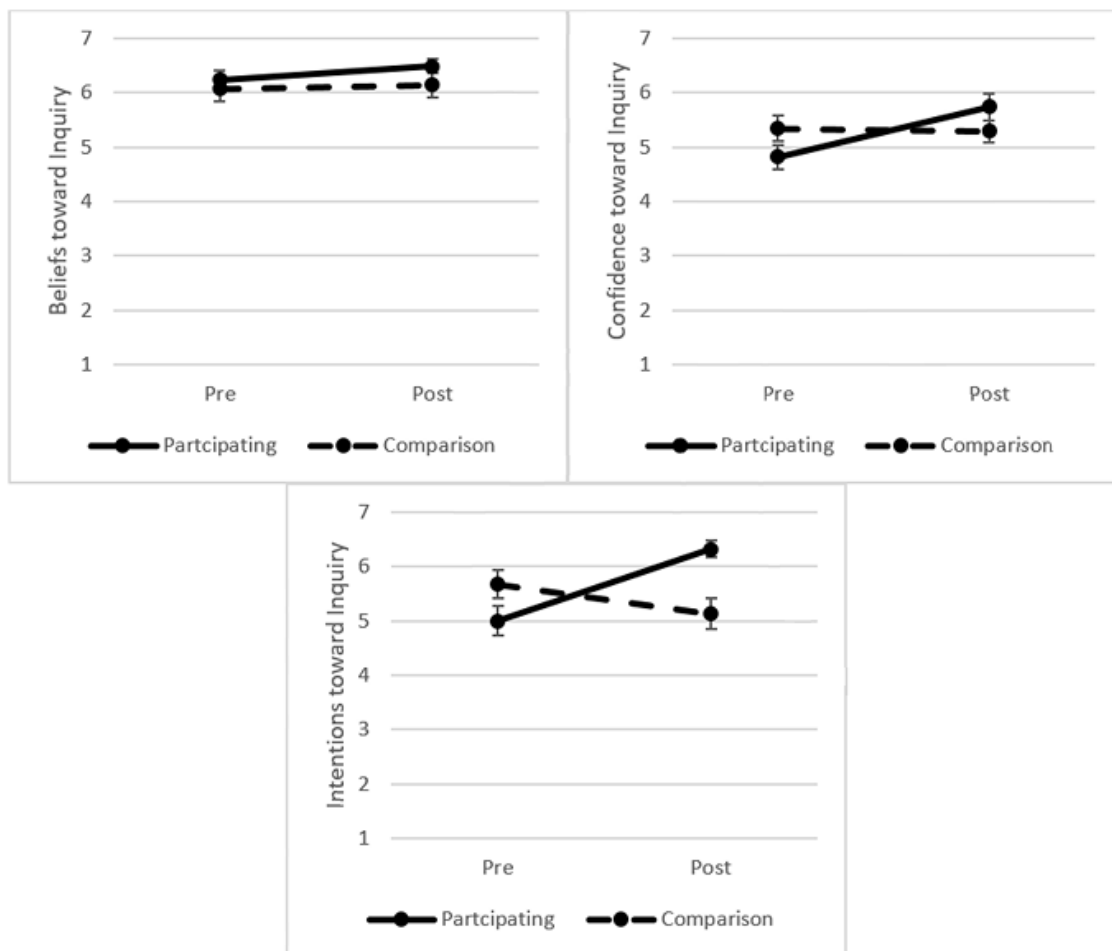


Figure 2. Change in Beliefs, Confidence, and Intentions toward Inquiry Pre- to Post-Survey for Participating and Comparison Groups of Teachers

Research Question 5

A Wilcoxon signed-rank test was performed to determine if differences existed for the pre and post administration of the EQUIP observational protocol. Only 14 teachers were included in this analysis as teachers who did not participate all four semesters of the program were excluded. Results indicated that Discourse and Assessment were statistically significant and Instruction was marginally significant pre to post. Teachers scored higher on the post-observation for Discourse (Mdn = 2.8) than on the pre-observation (Mdn = 2.2), $p = 0.011$, $r = 0.48$. Teachers also scored higher on the post-observation for Assessment (Mdn = 2.4) than on the pre-observation (Mdn = 2.0), $p = 0.030$, $r = 0.41$. Additionally, teachers scored higher on the post-observation for Discourse (Mdn = 2.8) than on the pre-observation (Mdn = 2.2), $p = 0.055$, $r = 0.36$. These results indicate that teachers were using a slightly higher level of inquiry in their classrooms at the end of the two years as reported by means and levels of significance in Table 10.

Table 10.

Results of Wilcoxon Signed-Rank Test for Participating Teachers' Use of Inquiry

EQUIP Factors	Baseline	Post	<i>p-value</i>
	Fall 2015	Spring 2017	
	<i>M (SE)</i>	<i>M (SE)</i>	
Instructional	2.25(0.21)	2.77(0.25)	0.011*
Discourse	2.09(0.20)	2.66(0.24)	0.030*
Assessment	1.92(0.15)	2.48(0.23)	0.055†
Curriculum	2.13(0.18)	2.81(0.28)	0.118

Note: † $p < 0.10$ * $p < 0.05$

Scale: 1 (Pre-Inquiry), 2 (Developing Inquiry), 3 (Proficient Inquiry), 4 (Exemplary inquiry)

A Wilcoxon signed-rank test was also performed to determine if differences existed for the mid2 and post administration of the EQUIP observational protocol. Twenty-seven teachers were included in this analysis. Results indicated that Instruction and Discourse were statistically significant, and Curriculum was marginally significant mid2 to post. Teachers scored higher on the post-observation for Instruction (Mdn = 2.8) than on the mid2-observation (Mdn = 2.4), $p = 0.047$, $r = 0.271$. Teachers also scored higher on the post-observation for Discourse (Mdn = 2.2) than on the mid2-observation (Mdn = 2.0), $p = 0.050$, $r = 0.267$. Additionally, teachers scored higher on the post-observation for Curriculum (Mdn = 2.25) than on the pre-observation (Mdn = 2.00), $p = 0.089$, $r = 0.232$. These are shown in Table 11.

Table 11.

Results of Wilcoxon signed-rank test for Participating Teachers' Use of Inquiry (Year 2 only)

EQUIP Factors	Mid2	Post	<i>p-value</i>
	Fall 2016	Spring 2017	
	<i>M (SE)</i>	<i>M (SE)</i>	
Instructional	2.33(0.19)	2.75(0.14)	0.047*
Discourse	2.11(0.29)	2.50(0.15)	0.050*
Assessment	2.07(0.18)	2.36(0.14)	0.266
Curriculum	2.07(0.18)	2.40(0.16)	0.089†

Note: † $p < 0.10$ * $p < 0.05$

Scale: 1 (Pre-Inquiry), 2 (Developing Inquiry), 3 (Proficient Inquiry), 4 (Exemplary inquiry)

Discussion

Findings from this study provide evidence that the professional development program was effective in initiating the transitioning of teachers' beliefs and classroom practice. As discussed by Desimone (2009), results indicate a connection between professional development, changes in teachers' beliefs, and changes in teachers' practice. In particular, a focus on PD

elements as discussed in literature (Darling-Hammond et al., 2017) could account for changes noted over the course of the two-year PD.

Teacher Beliefs

Given the connection between individuals' experiences and beliefs (Raths, 2001), exploring teachers' beliefs based on their experiences in the PD was a way we could assess the effectiveness of the PD program. Drawing on prior work pertaining to the variety of beliefs that are relevant to better understand teachers' instructional choices and potential changes in practice (e.g., Canrinus, et al., 2012; Cross, 2009; Hofer & Pintrich, 2004), we measured teacher beliefs through the constructs Teaching Philosophy, Job Satisfaction, and Openness to Change. Results indicated that these beliefs increased over the course of the two-years teachers participated in the PD. Teaching Philosophy in particular indicated the most significant difference with teachers reporting a more student-centered belief toward teaching. This finding may be in response to the PD focusing on inquiry-based practices, which include student-centered methods. Teachers were actively engaged in reflecting on their own practice throughout the program along with experiencing inquiry-based instruction through a variety of PD activities. As Levitt (2002) indicates, unconventional professional development can lead to a transitioning teacher philosophy and that these changes in teachers' beliefs directly align with the focus of the PD teachers are experiencing. Further, Brand and Moore (2011) noted the importance of teachers being "active participants in both goal-setting and ongoing work of the professional development process" (p. 908). Rather than having data collection being a by-product of the PD, teachers became active participants of their growth, setting goals, revising existing lesson plans, and reflecting on their beliefs and practices as it related to their classroom. Teachers' beliefs related to Job Satisfaction and Openness to Change also increased over the course of the PD. Research related to Openness to Change is linked to teachers' use of innovative technologies and risk-taking (Baylor & Ritchie, 2002; Howard & Gigliotti, 2016). Openness to change and a willingness to take risks is important when teachers are testing different strategies and considering changes to their practice. Additionally, there is some evidence that attitudes about inquiry and teachers' openness to ideas and actions may be correlated (Meijer et al., 2016).

Job Satisfaction, related to teacher burnout (Wang et al., 2015) and professional identity (Canrinus et al., 2012), is of particular importance in light of a large percentage of teacher attrition reported for the field (Ingersoll et al., 2018). The evaluation of change between the participating and comparison group of teachers makes clear the importance of effective PD on transitioning teachers' beliefs. Our results indicate participating teachers' beliefs transitioned over the course of the biennium but the comparison group of teachers did not significantly change. In fact, the means of the comparison group were trending down. However, no changes were evident with Professional Commitment. Given that these constructs are closely connected with professional

identity, which is a more stable construct (Beijaard, 1995), this finding may not be surprising. However, as noted in the current study, professional identity is not rigid and factors such as a teachers' work environment, sense of agency, and personal and professional experiences could lead to change (Day et al., 2006). Perhaps results from this study make evident Rokeach's (1972) concept of belief systems where peripheral beliefs such as beliefs about inquiry are easier to change than beliefs that are core to a teacher's sense of self, professional identity.

Inquiry-Based Beliefs

It is interesting that teacher beliefs related to the seven inquiry practices did not change over the course of the two-year PD. Teachers' initial responses were generally positive and stayed the same throughout the two years. However, changes became evident when exploring their level of confidence in designing instruction and implementing instruction that is inquiry based with a significant difference pre to post for the participating group of teachers. Changes were more significant for the intent to implement inquiry with statistically significant differences found between the pre- to post-survey and for the participating group of teachers and with results indicating a significant difference in the post-survey means between the participating and comparison group of teachers. It is possible that teachers observing these practices being implemented and practicing implementing the strategies in their own classrooms made them more likely to respond that they intended to implement the inquiry practices. Given that beliefs are theorized and have been shown to be predictive of intentions and intentions is predictive of actions (Aelterman et al., 2016; Ajzen, 1996), the change in belief may indicate that teachers will be more likely to enact the list of inquiry practices. Again, no significant difference was found for the comparison group of teachers and more notable shifts were noted for the comparison group of teachers for decreasing intentions between pre- to post-surveys.

Inquiry-Based Instruction

Results indicate changes in teachers' implementation of inquiry-based practices in their classroom. In particular, significant changes were found with the instructional and discourse factors. The Instructional factor corresponded with teachers' promoting conceptual understanding, student engagement, teachers allowing students to explore content before explaining, teachers acting as a facilitator, and students applying concepts being learned to new situations (depth of knowledge demonstrated). The Discourse factor also increased significantly over the course of the PD. Discourse corresponded with teachers' level of questioning, the complexity of questions, ability to engage students with questions, discourse, investigations or reflection, and how discussions were facilitated (types of support and reasoning evident). Even for experienced teachers, transitioning to use these practices effectively can be very difficult as they require the implementation of rich tasks. In addition, teachers may need to transition their role in the classroom, where they may have previously directed the learning experiences rather

than facilitated the experiences for students. Assessment was found to be marginally significant and corresponded to teachers assessing and modifying instruction based on prior knowledge, being process focused with learning activities, encouraging reflection and higher-level thinking with students, using authentic assessment measures consistently and effectively, and encouraging explanations with support. Research indicates that PD involving ongoing coaching, with particular focus on including teacher reflection, leads to change in teacher practice (Teemant, 2014). The instructional coach could be one of the features of the PD program that accounts for the changes found in teachers' practice. These coaching sessions in addition to the modeled lessons and instructional strategies during workshop sessions and over the summer provided teachers with a picture of what inquiry looks like in practice. In addition, teachers had personal goals, which related directly to their own classroom practice. Since goals help direct attention and energy, influence strategy selection and planning, and ultimately affect performance (Locke & Latham, 2002), it is possible that these goals helped the teachers grow through the challenge of developing new skills with inquiry-instructional practices. With specific goals that aligned to a rubric describing the target pedagogical outcomes, teachers could attend to an attainable practice, use feedback to monitor their progress towards goal attainment, and plan steps for improving their inquiry-based instructional practices. It is possible that despite only focusing on one goal at a time, teachers were influencing other areas of inquiry since many of the ideas related to one another. For example, meaningful questioning (Discourse) would likely lead to students being more active (Instructional) and soliciting explanations (Assessment). It is also important to note that while teachers use of inquiry increased over the course of the program, many of them were still at the developing inquiry level. The time it takes to transition practice seems to be extensive and may indicate the need for continued PD and support to maintain and further transition practice.

Differences were also noted for the 27 teachers who participated in the second year of the PD. The Assessment factor was not significant for this group, but the Curriculum factor was marginally significant. The Curriculum factor corresponded with the depth of content in the lesson as well as connections to the big picture, flexibility during investigations, the connectedness of the content and the investigations, and students being able to record information in non-prescriptive ways and communicate effectively. It is possible that the focus of the summer institute during the second year might account for this change. In the second year, the PD focused on project-based instruction with teachers designing a unit of instruction aligned to this method. Rather than focusing on individual lessons, a focus on a unit of instruction might have helped teachers see overarching concepts with the content they were teaching and how to make these more evident in their instruction. It is also likely that the job-embedded approach of the PD as recommended in current literature (Shirrell et al., 2019) provided teachers with the support needed to transition their practice.

Limitations and Conclusions

A limitation for this study was the attrition of teachers, which reduced the sample size. The small sample size increased the potential for Type II error with the ANOVAs conducted. However, it was preferable to keep the significance level α at 0.05 rather than potentially conflate results. It is possible that additional significance might have been found with a larger sample size of teachers. In addition to reducing the sample size, this attrition made some of the PD efforts more challenging as the facilitators needed time to build rapport with the teachers and teachers needed time to develop a sense of community with each other.

Meaningful PD can be challenging. Participating teachers in our study were required to be active rather than passive in the process. They were challenged to think deeply about their own practice, create professional goals that would lead to changes in their practice, and modify their instruction based on these goals. The intensity of the PD may be one reason we experienced a lot of transition in the program despite getting very positive feedback from the participating teachers. Being engaged in this type of PD is different than what is traditionally experienced by many teachers and calls for a level of commitment and engagement that may be taxing on their time and mental energy. We do not make this statement to be disparaging toward teachers who may have dropped the PD, but to share a challenge that PD developers and implementers may face when engaging in these activities. Despite challenges faced by teachers and facilitators, PD can result in changes in beliefs and practice as was evident in this study. It is also important to note that changes in teachers' beliefs and practices were potentially informing one another. Teaching using inquiry might have changed teachers' beliefs and self-efficacy and vice versa as literature indicates that the relationship between teacher beliefs and practice is "reciprocal, but complex" (Levin, 2015 p. 70). The job-embedded approach and coaching aspects of the PD could also inform educators and administrators as they consider future PD activities. A way that these aspects of PD could be included is through instructional coaches. While requiring a significant investment by a school or district, instructional coaches could provide the type of PD that builds on successful elements included as part of the current study as well as providing the on-going, context-specific experiences for teachers. It is also important to have the support from administrators, without including an evaluative component. This may include peer mentor programs, which would include many elements of the PD reported on in the current study, such as being job-embedded, collaboration with other teachers, and instructional support.

McGee and colleagues (2013) noted that future research regarding PD needed to examine "how teachers are able to translate their new learning into classroom experiences for their students" (p. 25). This study is illustrative of how PD can affect changes in beliefs and practices, which could ultimately influence student learning.

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