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Changing inquiry practices and beliefs: the impact of an inquiry-based professional development programme on beginning and experienced secondary science teachers

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This study explores how an inquiry-based demonstration classroom in-service programme impacted the beliefs and practices of 14 secondary science teachers. Both structured and semistructured interviews captured in-service programme participants' beliefs, while in-class observations of participants documented their instructional practices. An analysis of the data revealed that the in-service programme had an impact on the participants, but the impact varied among the six induction and eight experienced teachers: the induction teachers changed their beliefs more than their practices, whereas the experienced teachers demonstrated more change in their practices than their beliefs. Ultimately, the changing belief systems of beginning teachers may have resulted in the limited use of student-centred practices, whereas the established belief systems of experienced participants may have been conducive to student-centred practices. On the basis of the findings of this study, implications for professional development programmes are discussed.

Introduction

Science teachers in the USA have an articulated vision for science instruction in their classrooms. According to the *National science education standards* (National Research Council (NRC) 1996), a document developed to guide K-12 science education, students in science classes should engage in student-directed inquiries about scientific phenomena, encounter instruction that allows for the refinement of their critical and scientific thinking skills, and learn to work collaboratively with their peers as they engage in science investigations. To assist science teachers in creating classrooms that represent this reform-based vision, professional development programmes need to be developed, enacted, and evaluated. Ideally these programmes will last for several years, assist science teachers in refining both their beliefs and practices, and connect directly to organizational reform (Loucks-Horsley *et al*. 1998). Unfortunately, most professional development opportunities are of short duration (one to two years), provide experiences that may or may not initiate a change in beliefs and practices, and align with district mandates instead of organizational reform (Fullan 1991). Meeting the needs of today's science teachers for tomorrow's classrooms requires the creation and evaluation of plausible in-service programmes that support the vision of *National science education standards* (NRC 1996), while bridging ideal and actual

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professional development opportunities. The Inquiry-Based Demonstration Classroom (IBDC) in-service programme is one model of professional development that bridges the gap between ideal and current in-service practices and promotes reform-based instruction in the science classroom (Luft and Pizzini 1998); specifically, the practice of science as inquiry.

This study continues the exploration of demonstration classroom in-service programmes. It specifically explores how an IBDC in-service programme impacted the extended inquiry instruction of secondary science teachers, with specific attention given to (a) changes in behaviours that are conducive to inquiry instruction, (b) changes in beliefs about inquiry instruction, (c) beliefs about an inquiry-based in-service programme, and (d) differences between beginning and experienced science teachers. This study contributes to the literature on demonstration classroom in-service programmes and provides additional information about the change secondary science teachers experience as they participate in an in-service programme.

Programme context

IBDC in-service programme

The IBDC demonstration classroom programme attends to the principles of effective professional development for science teachers by addressing the specific needs of adult learners, creating ample follow-up opportunities for teachers to examine their learning of a new practice, fostering a context in which science teachers can reflect upon new information and connect it to their current programme or practice, employing a constant and embedded evaluation effort that provides direction to the in-service programme, and utilizing models and methods that represent sound science and science pedagogy (O'Brien 1992, Loucks-Horsley *et al*. 1998). The resulting programme structure consists of a preprogramme and programme with various forms of follow-up including visitations to a classroom that is actively participating in an extended inquiry cycle in science. This programme varies from the earlier Problem Solving Demonstration Classroom in-service programme (see Luft 1998, 1999a, Luft and Pizzini 1998) in that electronic discussions, moderated by the programme coordinator, were added as a form of follow-up. In addition, the observational format was modified to encourage in-service participants to visit one another and the demonstration teacher. By providing participants with additional experiences to interact and observe one another, participants had added opportunities to socially explore and reframe their beliefs and practices of extended inquiry instruction with one another.

In order to address the central IBDC in-service programme goal of having participants develop beliefs and practices conducive to the implementation of extended inquiry lessons, participants learned about a model of inquiry, utilized it in their classrooms, and examined and reflected upon their enacted lessons. The model of extended inquiry advocated throughout the programme was the Search, Solve, Create, and Share (SSCS) problem solving model (see Pizzini *et al*. 1988, Pizzini *et al*. 1989, Luft *et al*. 1997). A SSCS problem-solving cycle typically lasts eight or more one-hour class periods and is consistent with the recommendations for 'science as inquiry' as stated in the *National science education standards* (NRC

1996). The term '*extended inquiry cycle*' refers to an SSCS problem-solving cycle that lasts three days or longer.

The IBDC in-service programme began with a six-day preprogramme. During the spring, participants attended a one-day workshop that provided an orientation to inquiry-based science instruction. In the summer, participants engaged in an extensive five-day workshop in which they explored, experienced, and processed an extended inquiry cycle while also developing an extended inquiry cycle to enact in their classrooms. Throughout the school year, participants implemented extended inquiry cycles in their classrooms while they engaged in various types of follow-up activities. The interplay between classroom implementation and follow-up activities provided participants with an ongoing opportunity to enact, reflect upon, and refine their practices while exploring their knowledge and beliefs about extended inquiry cycles.

Four types of follow-up opportunities maximized the contact among participants and programme staff. First, participants could observe selected lessons within the extended inquiry cycle of a demonstration teacher or another in-service programme participant. To facilitate the observations and the dialogue between the participants and one another or the demonstration teacher, each participant received training on observing peers and four days of release time for observations. Second, participants received feedback from the programme director or programme coordinator in a clinical supervision format (Acheson and Gall 1992) about their implementation of the extended inquiry cycle. The topic of each supervisory visit varied by participant, yet was consistent with implementing an extended inquiry cycle. Participants, for example, elected to receive feedback on organizing a classroom lesson that facilitated identifying researchable questions, managing individual student investigations, and creating student groups to analyse student data. Third, five one-day meetings occurred throughout the IBDC in-service programme to specifically address the expressed concerns of programme participants. These meetings provided information on maximizing an observation of the demonstration teacher and peers; cooperative learning in the extended inquiry environment; alternative assessments in a learner-centred format; and descriptive, correlational, and experimental research in the extended inquiry cycle. The final meeting required participants to reflectively process the entire IBDC in-service experience. Fourth, participants communicated electronically with one another and the programme staff. Throughout the year, the programme coordinator facilitated electronic discussions that resulted in participants sharing their ideas for extended inquiry cycles, discussing the individual lessons they implemented, and reflecting upon various aspects of the extended inquiry experience (e.g. assessing students, the role on inquiry in science class, forms of inquiry, student achievement). Periodically, participants posted questions to the group and fellow participants replied promptly with statements about similar experiences, questions to clarify the problem, or advice to solve the dilemma.

Two previous demonstration classroom in-service programme studies have explored the beliefs and practices of upper elementary participants. Luft (1999a), in a year-long exploratory study of the beliefs of teachers who were involved in a demonstration classroom in-service programme, found that participating teachers addressed their instructional needs pertaining to problem solving, developed a view of the student in the context of problem solving, redefined their understanding of problem solving, reflected upon their own instructional practice, and

engaged in a collegial and mentoring dialogue with peers. Luft and Pizzini (1998), in a pre- and postexamination of the practices of participants involved in a demonstration classroom in-service programme, found that participating teachers significantly increased the amount of time that students worked in cooperative groups. In addition, they found that students during problem solving lessons significantly increased in their active participation, and significantly improved in their generation of researchable questions and their ability to design of experiments. Whereas Luft (1999a) identified salient beliefs of participants about the in-service programme and Luft and Pizzini (1998) observed changes in teachers' behaviours, neither study explored the change in inquiry practices and beliefs of participants involved in the in-service programme.

Science teachers and inquiry instruction

As science teachers participate in professional development programmes that are committed to reform-based instruction, they will encounter the call for science instruction within an inquiry framework (NRC 1996). In the USA, the *National science education standards* (NRC 1996) specifically states that inquiry instruction with students should include identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations. In an effort to be developmentally appropriate for science students, the 'science as inquiry' standards vary in defined abilities and concepts for the K-4, 4-8 and 9-12 grade levels. Implementing such instruction in the science classroom requires that teachers engage in instructional approaches that entail using actions that guide and facilitate student learning, assess the learning of students and their own instruction, craft environments that are conducive to learning science, and develop school programmes that support inquiry-based science (NRC 1996). The complexity involved in learning and implementing inquiry instruction suggests that professional development programmes should be constructed to address the practices and beliefs of science teachers.

Learning how to implement inquiry instruction requires that science teachers participate in professional development programmes that have been developed with attention to the research surrounding in-service teacher education. O'Brien (1992), in a meta-analysis of in-service programmes, concluded that presentations about the theory and concepts underlying the instruction are critical. Both theory and concepts provide science teachers with information that supports their use and understanding of methodology. In addition, science teachers need to an engage in an experience that simulates the advocated methodology (O'Brien 1992). By participating in an experience, teachers can understand the student's perspective of the lesson and the instructional process surrounding its implementation. Loucks-Horsley *et al*. (1998) suggested that an inquiry experience should demonstrate the unification of content and process. This experience, they argued, will assist science teachers in understanding the processes within the inquiry approach. Throughout the professional development programme, science teachers need to receive feedback about their practice from their peers and the coordinators or directors of the professional development programme (O'Brien 1992). Providing feedback to programme participants directs the development of their instruction, which can ultimately facilitate student learning. Intertwined with one another, these pro-

gramme components can assist a science teacher in learning the theory and developing practices associated with inquiry instruction.

Yet providing these basic programmematic experiences is not enough. Attention also needs to be given to the teachers' beliefs, which are interactive with their practices (Richardson 1996). According to Richardson (1996: 104), 'Beliefs are thought to drive actions; however, experiences and reflection on action may lead to changes in and/or additions to beliefs'. Science teachers need to explore and examine their underlying beliefs about teaching and learning inquiry in order to assimilate an accurate representation of this reform into their conceptual framework (Yerrick *et al*. 1997). Creating this environment of understanding for science teachers requires that staff development specialists continually attend to the representation of inquiry within the programme. This representation should stay consistent with stated standards. Additionally, science teachers should have multiple opportunities to reframe or redefine their current beliefs related to inquiry instruction. Richardson (1996) concluded that teachers need to examine their beliefs through conversations about beliefs and practices that are situated within dimensions of schooling, and that such discussions should be directed by teachers in terms of agenda, process, and content. When she and her colleagues concluded a staff development programme that consisted of group and individual examinations of classroom practice and beliefs, they found that the teachers had changed their beliefs (Richardson 1994). During professional development programmes it is important to provide consistent representations of inquiry and to hold purposeful conversations that specifically attend to the development of teachers' beliefs and practices.

Methods

Participants

Fourteen secondary science teachers in a southwestern US city participated in an 18-month IBDC in-service programme. When the teachers enrolled in the programme in the spring, eight reported middle school assignments and six reported high school assignments (table 1). Most of the teachers, 11, indicated they were working primarily with economically disadvantaged Hispanic-American students, whereas three teachers indicated they were working primarily with white middle-class students. These teachers also noted a range of teaching experience that spanned 0-17 years of experience, with an average of five years of experience. The participants were evenly divided in regard to gender with seven males and seven females comprising the group. All of the teachers reported that inquiry instruction was important, yet only six teachers indicated that they implemented any type of inquiry and two teachers had previously utilized the IBDC in-service programme model of extended inquiry in their classes. All of the teachers received a stipend for participating in the in-service programme, and all consented to participating in the IBDC in-service programme study.

The teachers in the IBDC in-service programme were periodically divided into two groups in order to facilitate the analysis of the data. The beginning teacher group was composed of three teachers who were preparing for their first year of teaching, two teachers who were just completing their first year of teaching, and one teacher who was just completing her second year. Respectively, these six

teachers were assigned middle school life science, middle school physical science, high school physical science, high school environmental science, high school biology, and high school biology and chemistry. The experienced teacher group was composed of eight teachers of which one was completing his third year, one was completing his fourth year, two were completing their fifth year, two were completing their ninth year, one was completing her 13th year, and one was completing her 17th year. Respectively, these eight teachers were assigned high school biology, middle school physical science, high school biology, high school chemistry, high school biology and chemistry, middle school life science, middle school life science, and high school biology. The induction and experienced teachers were not formally grouped during the IBDC in-service programme. Instead, all of the teachers continually engaged in activities together throughout the in-service programme, as it was assumed that all of the teachers were intellectuals capable of contributing to the advancement of the practice of one another (Giroux 1988).

Data collection and data analysis

For this study, I utilized a parallel/simultaneous mixed-methodology approach during the data collection and analysis (Tashakkori and Teddlie 1998). This paradigm combines both qualitative and quantitative methods to give both breadth and scope to the research project (Greene *et al*. 1989). In conjunction with the utilization of both qualitative and quantitative methods, decisions regarding data collection and analysis were made to understand the different aspects of the beliefs and practices of the secondary science teachers. As a result, data collection techniques existed simultaneously while the data were analysed throughout the study.

Observations of extended inquiry cycles. In order to assess the level of extended inquiry instruction among in-service participants, a rubric was developed that represented inquiry practice as espoused in the IBDC in-service programme. The first step in constructing the Extended Inquiry Observational Rubric (EIOR) (Luft 1999b) entailed an examination of the IBDC in-service programme goals. The programme director advanced the programme goals into eight categories describing inquiry instruction: Cooperative learning, Teacher as guide, Assessment, Student communication and student action, Inquiry question, Designing and conducting a scientific investigation, Gathering and analysing data, and Sharing of extended investigation. These categories ultimately described various aspects of extended inquiry instruction that represented teacher behaviours, or student actions that resulted from teacher behaviours. Each category was further elucidated into five performance levels through a process of ongoing referral to the *National science education standards* (NRC 1996), the SSCS Implementation Rubric (Luft 1998), the Secondary Teacher Analysis Matrix (Gallagher and Parker 1995), the Constructivist Learning Environment Survey (Taylor *et al*. 1997), and the extended inquiry practice of programme participants. Each level received a point value, ranging from 1-5, which corresponded to varying degrees of implementation of an extended inquiry cycle. A score of 5 represented the highest competency, while a score of 1 the lowest. The complete rubric and a detailed account of its development can be found in Luft (1999b).

Deriving a score on the EIOR in each category for a participant entailed a process of observation, data collection, and consensus. When a participant enacted

an extended inquiry cycle, both the programme director and the programme coordinator observed the participant and collected field notes from various lessons that comprised the cycle. Observations and field note collection followed the guidelines discussed by Bogdan and Biklen (1992). Each participant was observed by either the programme director or the programme coordinator during each phase of the extended inquiry cycle. These independent observations (e.g. the director would observe at least one day of the Search phase, while the coordinator would observe at least one day of the Solve phase) resulted in a total of at least four observations of the participant; two observations made by the director and two observations made by the coordinator. Occasionally, participants had lengthy extended inquiry cycles that allowed both the director and coordinator to observe different days of the same phase. During an observation, the director or coordinator took extensive field notes and determined the description within each EIOR category that best represented the participant's current implementation level of the extended inquiry cycle. The final participant score on the EIOR represented a process of consensus in which the director and coordinator discussed each category score and corresponding field notes, then agreed upon a point value. Utilizing a process of consensus ensured reliable and consistent scoring; a common concern with alternative assessments (Herman *et al*. 1992). Both the director and coordinator determined overall EIOR scores for participants' extended inquiry cycles at the midpoint of the programme and at the conclusion of the programme.

The director elected to use a one-group pre-test-post-test design (Campbell and Stanley 1963) to assess the effects of the IBDC in-service programme on the extended inquiry instruction of participants. Prescores represented the participant's first EIOR scores, whereas postscores represented the participant's final EIOR scores. Analysis of the participant's EIOR scores entailed the use of the dependent *t*-test in order to determine if significant change had occurred within categories during the IBDC in-service programme.

Standardized interviews. A standardized interview (Berg 1998) captured participants' beliefs about teaching throughout the IBDC in-service programme. *The Teachers' Pedagogical Philosophy Interview* (TPPI, Salish I Research Project 1997) is a standardized 50-item interview instrument that explores eight different attributes related to teacher actions and teacher philosophies. Based upon recommendations from Salish I Researchers and the instructional goals of the IBDC in-service programme, pre- and post-interviews consisted of eight questions from the TPPI. The selected questions reveal teaching philosophies, and each question contains response categories that identify didactic, transitional, conceptual, or constructivist beliefs (Salish I Research Project 1997).

The programme director, programme researcher, or the programme coordinator interviewed each participant prior to the summer workshop and at the conclusion of the school year. Interviews lasted 30-45 minutes and were audiotaped. The director and researcher independently coded, then collaboratively coded the transcribed TPPI interviews (Miles and Huberman 1994). A TPPI coding map of each question indicated if the pre- and post-answer represented didactic, transitional, conceptual, or constructivist tendencies (Salish I Research Project 1997). The TPPI questions and scoring protocol utilized in this study can be found in Brockmeyer (1998). Analysis of the coded answers entailed recording answers and

examining them for trends within a participant, and with non-parametric analysis methods to understand the trends between participants.

Semistandardized interviews and documents. Capturing participants' beliefs about the IBDC in-service programme involved conducting semistandardized interviews (Berg 1998) with participants and collecting numerous in-service related documents. The pre-, mid-, and post-interviews were conducted, respectively, prior to the summer workshop, in early January, and at the conclusion of the school year. The director, researcher, or coordinator asked participants for metaphors describing their role in the classroom, their definitions about inquiry, and their experiences with extended inquiry instruction. Berg (1998), Briscoe (1991), and Coffey and Atkinson (1996) influenced and directed the formation of these interview topics. The complete interview schedule can be found in Brockmeyer (1998). When possible, the 30-45 minute semistandardized interview occurred with the standardized interview. Collected documents provided another source of data about participants' beliefs and included field notes documenting participants' practices, notes from follow-up meetings, and e-mail correspondence. The collected documents complemented the interview data and provided information about participants' experiences that could not be obtained through any other means (Marshall and Rossman 1989).

The director and researcher inductively analysed the interview transcripts and collected documents to create individual cases that portrayed each participant. Cases were compared to one another in order to understand the trends pertaining to the conditions and the context within the in-service programme as well as the perceptions, trends, and change among participants (Miles and Huberman 1994). The use of multiple data sources, multiple coders, repeated data collection, and cross-case comparisons achieved triangulation (Maxwell 1996). Multiple sources included documents and interviews, while two researchers analysed all data, which was collected repeatedly throughout the year. Triangulation was emphasized for the reason of presenting meaningful propositions and to reduce the bias inherent in qualitative research (Mathison 1988).

Study limitations

This study examines the impact of the IBDC in-service programme on participants. Even though the study adhered to research protocol, there are limitations that need to be acknowledged. First, the population in this study was small and composed of volunteers. Even though this is perceived as a limitation, it should be pointed out that the size of the participant group is typical of in-service programmes. Second, multiple comparisons were made (dependent *t*-tests) within one population of participants, with the representative categories examined as independent hypotheses. No adjustment in alpha level occurred during the comparisons as type II and type I errors were considered to be equally important (Schmidt 1996). Third, the programme staff had roles that involved researching beliefs and practices of participants. Although this may have confounded the data collection, it may have also provided access to data not typically revealed to researchers. These limitations notwithstanding, the design of the study and the use of the research methods lend confidence to the researcher in drawing conclusions from the data.

Results

Changes in behaviours conducive to inquiry instruction

As a collective group, most of the IBDC in-service programme participants utilized extended inquiry cycles in their classrooms (table 1). Of the 14 participants in the programme, 10 teachers implemented at least two extended inquiry cycles, whereas two teachers implemented an extended inquiry cycle only once. Only two teachers did not implement extended inquiry cycles during the IBDC in-service programme. The 10 teachers who implemented two or more extended inquiry cycles also participated in one, two, or three demonstration classroom visits, and they received feedback on their extended inquiry instruction during at least eight different occasions. The two teachers who implemented one extended inquiry cycle did not participate in the demonstration classroom visits, but they did receive feedback on their extended inquiry instruction during at least four different occasions. The teachers who did not implement any extended inquiry cycles also did not participate in any demonstration classroom visits. All of the teachers in the IBDC in-service programme attended at least three of the planned follow-up meetings.

Examining the records of practice in regard to induction and experienced teachers revealed that the induction teachers were slightly less likely to implement extended inquiry cycles than their experienced peers. Of the eight experienced teachers, five implemented three or more extended inquiry cycles, two implemented two extended inquiry cycles, whereas only one implemented no extended inquiry cycle. Of the six induction teachers, one implemented four extended inquiry cycles, two implemented two extended inquiry cycles, two implemented one extended inquiry cycle, and one implemented no extended inquiry cycle.

In order to understand the changes in behaviours among participants who implemented extended inquiry lessons, a dependent *t*-test analysis of the eight

Table 1. Descriptions of participants and extended inquiry cycles implemented.

Participant	*Years of teaching experience*	*High or middle school assignment*	*Number of cycles*	*Average length of cycle (days)*
Susan	17	High school	2	11.5
Jose	13	Middle school	3	15.0
Josie	9	High school	4	9.3
Joyce	9	Middle school	3	15.0
Sam	5	High school	2	9.5
Jill	5	High school	3	10.0
Steve	4	Middle school	3	8.7
Alexis	3	High school	0	0
Jennifer	2	High school	4	15.7
Sally	1	High school	2	10
Bruce	1	High school	0	0
Jeff	0	Middle school	2	11
Kevin	0	Middle school	1	10
Tina	0	High school	1	7

Table 2. Means, stand deviations, *t*-values, and significance of extended inquiry implementation.

Component ($n = 10$)	*Prescores*		*Postscores*	*t-value* ($df = 9$)	*Significance (2-tailed)*
Cooperative learning	*M*	2.40	3.20	2.45	0.04*
	SD	0.52	0.79		
Teacher as guide	*M*	2.40	3.20	2.75	0.02*
	SD	0.84	0.79		
Assessment	*M*	1.70	2.80	3.97	0.01**
	SD	0.67	0.79		
Student communication and action	*M*	1.70	3.00	4.33	0.01**
	SD	0.48	0.67		
Inquiry question	*M*	2.10	3.30	3.34	0.01**
	SD	0.74	0.82		
Designing and conducting a scientific investigation	*M*	2.20	2.90	3.28	0.01**
	SD	0.63	0.56		
Gathering and analysing data	*M*	1.70	2.40	2.33	0.05*
	SD	0.48	0.84		
Sharing of extended investigation	*M*	1.90	2.80	3.25	0.01**
	SD	0.57	0.63		

Note. * $p \leq 0.05$. ** $p \leq 0.01$.

categories in the EIOR was conducted. The average first and final EIOR scores of the 10 participants who implemented two or more extended inquiry lessons were compared. A dependent *t*-test analysis was conducted to examine the following null hypothesis: there was no significant difference between the first and the final EIOR category scores of the individuals who implemented extended inquiry cycles.

Table 2 reports the means and the standard deviations for the 10 participants who completed at least two extended inquiry cycles. Pre-scores represent the first extended inquiry cycle, whereas post-scores represent the final extended inquiry cycle. Table 2 also reports the dependent *t*-values and significance level of the pairwise comparisons. During the calculation of the *t*-scores, each category represented a different hypothesis worthy of consideration. This assumption acknowledges the concern for multiple tests within the same population. Significance at the 0.01 level existed in the following categories: Assessment, Student communication and action, Inquiry question, Designing and conducting a scientific investigation and Sharing of extended investigations. Significance at the 0.05 level existed in the remaining categories: Cooperative learning, Teacher as guide and Gathering and analysing data.

Changes in beliefs about inquiry instruction

The TPPI interviews revealed that the participants in this programme held didactic, transitional, conceptual, and constructivist philosophies about teaching (table 3). Didactic and transitional beliefs are indicators of teacher-centred philosophies, whereas constructivist and conceptual beliefs align with student-centred practices (Salish I Research Project 1997). Generally, participants tended to hold

Table 3. Percentage responses by teacher group on the TPPI interviews.

Teachers' responses (teachers, number of total responses)	*Didactic % (responses)*	*Transitional % (responses)*	*Conceptual % (responses)*	*Constructivist % (responses)*
Induction (6, 48)				
Initial	16.6 (8)	25.0 (12)	39.6 (19)	18.8 (9)
Final	31.2 (15)	18.8 (9)	37.5 (18)	12.5 (6)
Experienced (8, 64)				
Initial	15.6 (10)	32.8 (21)	32.8 (21)	18.8 (12)
Final	15.6 (10)	31.3 (20)	35.9 (23)	17.2 (11)
Total (14, 112)				
Initial	16.1 (18)	29.5 (33)	35.7 (40)	18.7 (21)
Final	22.3 (25)	25.9 (29)	36.6 (41)	15.2 (17)

more student-centred than teacher-centred beliefs with conceptual responses occurring more frequently than didactic and constructivist responses.

An examination of the change of individual beliefs and the change among induction and experienced teachers revealed subtle differences. An examination of individual TPPI interviews revealed that four of the six induction teachers changed three or more of their responses to a different category (e.g. the initial answer was coded as didactic, and the final answer was coded as conceptual), whereas the other induction teachers changed only one or two of their responses. Of the experienced teachers, only two changed three or more of their responses to a different category, while four and two teachers, respectively, changed two and one response to a different category. The changes revealed that the number of didactic responses increased for induction teachers and at least stayed the same for experienced teachers, and the number of conceptual and constructivist responses decreased for induction teachers and constructivist responses decreased for experienced teachers. Table 3 represents the initial and final number of responses in each category for induction, experienced, and all participants. A non-parametric analysis between initial and final TPPI responses for induction, experienced, and all participants and between the TPPI responses for induction, experienced, and all participants revealed no significant differences. It should be noted that although these changes are reported as not statistically significant, they may be significant to the participants.

Beliefs about an IBDC in-service programme

The highly individualized participant responses and documents collected during the IBDC in-service programme demonstrated that each participant held a unique perspective throughout. Although there were several apparent differences among the participants, three trends pertaining to participants within the IBDC in-service programme became evident at the completion of the interview and document analysis. The following discussion addresses the three emergent trends that span all participants. Throughout the discussion, pseudonyms are utilized to ensure anonymity.

Participants modified their views about their role in the classroom and about inquiry instruction. Throughout the IBDC in-service programme, the analysis of interviews and documents revealed participants revising their perspectives about being science teachers and their views of inquiry instruction. Revisions varied depending upon the individual and were influenced by the context of the participants' instructional assignments and their participation in the IBDC in-service programme. Most of the participants in the programme reframed their science teaching views towards a more personal orientation (Feiman-Nemser 1990). Susan provides a representative example of this revision process in which participants developed an enhanced view of the interaction that existed between themselves and their students. At the beginning of the in-service programme, she described her teaching as a cup. She felt that instructional ideas came in, instructional ideas left, and that certain instructional ideas were continually drawn upon to nourish her teaching. During the final interview, Susan specifically stated that her initial description and understanding of science teaching was limited. By the conclusion of the in-service programme, Susan characterized herself as a director of a play who enabled students to give their best performances. She felt her interactions with students were critical and ultimately informed her instruction, which allowed her to guide students towards accepted scientific ideas.

Another form of revision that three IBDC in-service participants experienced entailed a reframing of science teaching views towards a more utilitarian perspective. These participants, overwhelmed with the low motivation and low abilities of their students, revised their science teaching roles to traditional models that entailed direct instruction and skill development. Greg is a representative example of this shift found in a few IBDC in-service programme participants. At the beginning of the in-service programme, Greg viewed himself as an advocate for students. He felt a responsibility to understand his students' perspectives and to be responsive to their needs throughout instruction. By the conclusion of the IBDC in-service programme and after implementing an extended inquiry cycle, Greg described himself as an entertainer. He was forced to captivate the students, then introduce instruction that emphasized rote learning skills (e.g. worksheets, crossword puzzles)—not inquiry science.

For all participants, explanations of inquiry instruction advanced to varying degrees over the course of IBDC in-service programme. Participants replaced general views about inquiry instruction with specific science-related inquiry tenets as articulated in the *National science education standards* (NRC 1996). For example, Susan initially stated that inquiry instruction occurred in a variety of ways, but primarily from hands-on experiences. At the conclusion of the IBDC in-service programme, Susan spoke about the importance of students identifying questions, developing investigations based upon their questions, and representing their findings in graphs and tables. Although some participants did not refine their notion of inquiry instruction to the level discussed by Susan, all advanced their understandings of inquiry instruction to include identifying a researchable question and investigating a question in which students did not know the answer.

Participants valued the extended inquiry cycles they implemented. When participants shared their best teaching experiences throughout the year, they spoke about their implemented extended inquiry cycles. Participants who did not explicitly implement cycles discussed the incorporation of versions of extended inquiry cycles into

other lessons and units. As participants implemented either type of cycle, they experienced students taking on new roles in their learning, they learned instructional techniques that could be used in different settings, and they felt inspired to plan and enact additional inquiry lessons. Jennifer, an experienced teacher, typifies the participants who readily identified the different roles exhibited by students. When asked about her best lesson, she spoke at length about her students and their abilities to ask one another questions, to design experiments, and to sceptically examine data. Her students had not encountered these roles before in their learning. After her initial extended inquiry cycle, Jennifer enthusiastically planned and implemented three additional extended inquiry cycles.

Participants also revealed the utilization of various techniques associated with extended inquiry cycles. As participants implemented extended inquiry cycles, they experienced various instructional techniques that were transferred to other science lessons. For example, Kevin, a first-year teacher, discussed extensively the extended inquiry cycle he and the programme director implemented together. He repeatedly indicated that this was his best teaching experience all year. Although he wanted to implement additional lessons, constraints related to student ability and classroom materials interfered with his ideal plans. He, however, utilized several instructional techniques from the co-taught lesson, such as forming cooperative groups, having students collect their own data, and organizing students to analyse their data. For Kevin, and participants similar to him, implementing an extended inquiry cycle provided him with an experience that he could draw upon and various methods he could utilize within other science lessons.

Participants gained support and assistance during the various follow-up components. Collected documents and recorded conversations revealed the support and assistance IBDC in-service programme participants derived from the various follow-up opportunities. Participants valued having programme staff observe and discuss their extended inquiry cycles, they appreciated the opportunity to observe their peers enact extended inquiry cycles, and they found it useful to gather ideas about different lesson plans and pragmatic issues related to the implementation of extended inquiry cycles from fellow participants. Additionally, the scheduled meetings provided another means of support as participants discussed planned lessons, successful lessons, and lessons that floundered. Jeff, for example, during one Saturday meeting heard Jose discuss a recent extended inquiry cycle with plants. Jeff talked to Jose at length about his lesson. Afterwards, they corresponded electronically as Jeff planned and enacted an extended inquiry cycle that was similar to Jose's plant cycle. The value of the follow-up experiences was further reiterated when participants expressed the need for additional follow-up opportunities that included planning and critiquing lessons, exploring various aspects of science related investigations, and discussing inquiry instruction with administrators.

As participants discussed various follow-up components in the IBDC in-service programme, it became evident that each participant uniquely capitalized upon the different forms of assistance. Whereas some participants observed their peers and asked for feedback on their instruction from programme staff, other participants diligently corresponded electronically with one another as they implemented extended inquiry cycles. The varying forms of follow-up provided participants with ample opportunities to seek support and assistance in a manner that

was conducive to their own professional growth in regard to implementing extended inquiry cycles.

Conclusions

Discussion

In this study, I specifically examined the impact of the IBDC in-service programme on participants. The findings from this study reveal changes in beliefs and behaviours of the in-service programme participants and the complex nature of teacher development. Discussion of these findings will begin with the impact of the in-service programme on the participants as a collective group, then proceed to the impact of the in-service programme on the induction and experienced participants.

As a group, participants in the IBDC in-service programme made statistically significant changes in their extended inquiry practices, yet changes in their beliefs were not statistically significant. The change in practices can possibly be attributed to participants' student-centred beliefs. Participants had an interest in implementing student-centred instruction, as was represented in their beliefs and their enrollment in the in-service programme, that may have facilitated the enactment of extended inquiry cycles and changes in their extended inquiry cycles. While participants' beliefs may have directed their inquiry practices, their inquiry practices did not noticeably affect their beliefs. The lack of change in participants' beliefs may be attributed to the stable nature of beliefs. Pajares (1992) concluded that beliefs are a result of personal experiences and are often difficult to change. Knowing that prior experiences in science classrooms formed the beliefs held by participants, it would be unlikely that an extensive year of professional development could significantly alter participants' beliefs. However, subtle changes in participants' beliefs may have occurred, but were not detected by the TPPI. This is plausible as interviews with participants revealed that the in-service programme reinforced their implementation of extended inquiry cycles and clarified their ideas about student-centred instruction. Yet even with this information, it can only be concluded that participants who held varied beliefs (e.g. didactic, conceptual, and constructivist) and participated in the IBDC in-service programme improved their implementation of extended inquiry cycles.

An examination of the changes in inquiry practice that occurred within the participant group reveals the complex nature of teacher development. Participants demonstrated significant change in their assessment of inquiry instruction, while their students exhibited a similar improvement in communication and activity during extended inquiry cycles. In addition, the students of participants significantly improved in developing researchable questions, designing and conducting investigations, and sharing the results of investigations. While students significantly improved in their gathering and analysing of data, this area was not at a competency equivalent to other extended inquiry cycle components. An examination of these pre- and post-scores in relation to the EIOR scale indicates that this significant change occurred at a lower level of performance than other statistically significant components. This demonstrates that learning to implement extended inquiry cycles is a developmental process. While participants readily adopted some aspects of extended inquiry cycles, other aspects needed additional instructional

assistance in order for participants to achieve higher competencies. The various instructional changes that participants made were ultimately affected by their current practices and beliefs, and the in-service programme. If learning to teach inquiry is acknowledged as a complex process, then teachers need various opportunities to understand the implementation of extended inquiry instruction. Similar to the constructivist approaches teachers utilize with their students (Fosnot 1996), professional development coordinators need to enact well-planned in-service programmes that allow participants to construct their knowledge about inquiry instruction.

While there are specific conclusions that can be drawn from the group of IBDC in-service participants, there are also important findings to discuss in regard to the induction and experienced teachers involved in the in-service programme. Induction and experienced teachers exhibited different changes throughout the in-service programme. Specifically, the induction teachers experienced more change in their beliefs than their practices, whereas experienced teachers demonstrated more change in their practices than their beliefs. Although it is accepted that there is a relationship between beliefs and practices (Richardson 1996), few studies have discussed how beliefs and practices differ between beginning and experienced teachers involved in professional development programmes.

In this study, similar to the Salish I Research Project (1997), beginning science teachers held pliable beliefs about teaching. Dissimilar to the Salish I Research Project (1997), the beliefs and practices of the induction science teachers eventually aligned. The beliefs of induction science teachers appeared to be impacted by school experiences (e.g. student abilities, district curriculum) and interactions with programme staff and fellow participants. Their changing beliefs may have constrained their implementation of extended inquiry cycles. Specifically, all induction teachers espoused the importance of inquiry instruction at the beginning of the in-service programme and they had numerous plans to implement such lessons. By the end, some induction teachers had implemented extended inquiry cycles and some had not. Corresponding to the different levels of implemented extended inquiry cycles were beliefs that had shifted towards student-centred instruction, and beliefs that had shifted towards traditional instruction. Ultimately, the changing beliefs of the induction teachers may have resulted in their limited implementation of extended inquiry cycles. Even though the induction teachers varied in their implementation of extended inquiry cycles, all valued the programme staff and experienced teachers who constantly reminded them of the importance of inquiry instruction. Given the pliable beliefs and practices of induction teachers, support programmes for induction teachers should extend beyond their first year in the classroom—a traditional focus of beginning teacher support programmes. Ideally, beginning science teachers should receive support and assistance for two or three years in order to reinforce reform-based beliefs and practices.

The experienced teachers in this study demonstrated more change in their practices than in their beliefs. The beliefs of experienced teachers in the IBDC in-service programme appeared to facilitate the implementation of extended inquiry cycles and the advancement of their notions regarding teaching and inquiry instruction. In addition, their beliefs were consistent throughout the in-service programme as new practices were tried and notions of teaching and instruction were reframed. Ultimately, their established beliefs systems may

have been conducive to their use of extended inquiry cycles and may have facilitated the changes they experienced in their extended inquiry cycles. Creating additional shifts in beliefs towards more student-centred epistemologies requires a facilitated in-depth examination of beliefs (Richardson 1994) or continued observation of student progress (Guskey 1986). For experienced teachers, this programme supported initial changes in practices that were consistent with their current beliefs. Continued involvement in professional development activities may foster changes in experienced teachers' beliefs that will alter their views of student learning, pedagogical approaches, or inquiry instruction.

This professional development experience impacted all of the participants, and provided induction and experienced teachers with different opportunities to move towards reform-based beliefs and practices. Most participants engaged in extended inquiry cycles, and most significantly improved their extended inquiry instruction. Induction teachers received the support they needed to challenge their beliefs pertaining to reform-based instruction while experienced teachers received instruction that facilitated changes in their use of extended inquiry cycles.

Implications

This study provides three suggestions for professional development coordinators who work with science teachers in short duration in-service programmes. First, similar to conclusions by Guskey (1986) and Franke *et al*. (1998), in-service programmes should be configured to attend to the diverse behaviours and beliefs of participants. In this in-service programme, attention was given to specific behaviours and beliefs that promoted inquiry science in the classroom. To foster the development of behaviours and beliefs conducive to inquiry instruction, participants had opportunities to explore their own behaviours and beliefs regarding inquiry instruction in different venues appropriate to their level of instructional need and learning style.

Second, in-service programmes should contain follow-up experiences with multiple opportunities for interaction. In the IBDC in-service programme, scheduled meetings, classroom visitations, and electronic discussions allowed programme staff and participants to process and expand their understanding of extended inquiry cycles. These different follow-up opportunities enhanced the impact of the programme by revealing the different aspects of extended inquiry instruction. Specifically, classroom visits presented actual inquiry examples, meetings provided instruction on topics important to participants, and electronic discussions allowed participants to process their understanding of extended inquiry cycles. Providing various opportunities for teacher development during an in-service programme acknowledges the complexity of teacher change and allows teachers to construct their own understandings of science instruction in a manner that is personally and professionally appropriate.

Third, induction science teachers, in the absence of a mentoring programme, may benefit by participating in in-service programmes. The induction teachers in this programme held beliefs that were subject to revision. Programme staff and experienced teachers provided an external stimulus that interacted with induction teachers' beliefs and reinforced the reform-based practices experienced during their preservice years. In addition, the induction teachers were not left to be

socialized within a school culture that may or may not have attended to reform-based practices.

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