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Developing teaching responsiveness to children's inquiry in science: A case study of professional development for pre-school teachers

Abstract

Supporting inquiry in the science classroom is challenging work, demanding that teachers utilize abilities for addressing and responding to children's inquiry. These abilities include, (a) knowledge of the various forms of in-class scientific inquiry; (b) abilities for evaluating elements of children's inquiry which teachers identify; and (c) a repertoire of instructional strategies, from which to choose in order to respond to children's in-class inquiry. Developing these abilities depends largely on teachers' preparation and subsequent professional development (PD) in teaching science. Our purpose in this paper is to describe the design of a professional development program (PDP) for pre-school teachers in Cyprus, seeking to help them develop teacher responsiveness to children's inquiry. We draw on data from an implementation of this PDP to illustrate how teachers have begun developing their sensitivity towards children's in-class inquiry and building a repertoire of responses.

INTRODUCTION

Scientific literacy includes more than simply understanding science content. NAS (1996) describes knowledge, processes, beliefs and, conceptual and epistemological understanding as the vital components of scientific literacy. Towards this direction, current science education reform efforts emphasize promoting inquiry in science teaching and learning (EC, 2007; NRC, 2011), based on the idea that engaging children in the various forms of authentic scientific inquiry can help them develop the knowledge and abilities required to develop scientific literacy.

“Inquiry” has been a dominant term in the rhetoric of past and current science education reforms. During the second half of the twentieth century, “good science teaching and learning” became increasingly associated with inquiry (Anderson, 2002). Among the most influential factor for inquiry teaching and learning is the role of the teacher. Firstly, the teacher is responsible for preparing and orchestrating learning activities that will engage children in scientifically authentic problem-based situations. Traditionally teacher preparation and professional development programs (PDPs) have placed a large emphasis on helping teachers prepare inquiry-based lessons (e.g., Jarvis et al. 2001; Lenton & Turner 1999).

Secondly, teachers need to monitor children's conversations for elements of inquiry (Louca, Tzialli & Zacharia, 2012) that are valuable, beneficial to learning, and in need of support, and respond to these in whichever form are presented in any classroom situation. This requires that teachers know how classroom-based inquiry looks and how it might be presented (discursively, theoretically, practically – hands on etc). To do so, teachers need to have experienced authentic scientific inquiry themselves, in order to appreciate all its facets. Thirdly, to better support children's inquiry, teachers need a repertoire of teaching strategies that they can draw from during teaching (ibid). They need to have a coherent view of, and about science and science education, which will then guide them through principles of deciding how and when to respond to the children's inquiry.

Our purpose in this paper is to describe the principles around which we designed a PDP for pre-school in-service teachers in Cyprus, seeking to develop teacher responsiveness to children's inquiry (Scott, 1998; Louca, Tzialli & Zacharia, 2012). By teacher responsiveness we refer to teachers' abilities to identify, interpret and evaluate, and respond appropriately to their children's inquiry (Louca, Tzialli & Zacharia, 2012). As a case in point, we provide data from an implementation of this PDP to illustrate how a group of teachers began to develop their sensitivity towards children's in-class inquiry and build their repertoire of responses.

THEORETICAL FRAMEWORK

Classroom-based children's inquiry

Literature from a variety of perspectives and intellectual traditions, concerning children's abilities for scientific inquiry shows a general consensus regarding the things we should value and promote in children's inquiry (e.g., Linn, Davis & Bell, 2004; Minstrell & van Zee, 2000; NRC, 2007; Osborne et al., 2004). However, this consensus does not extend to defining how scientific inquiry looks in the science classroom. Rather, it contends against a widely shared sense of inquiry as a pedagogical strategy, a method for teaching the traditional “content” of science (e.g., Hammer, 1995; 2004). According to this view, assessing the quality of children's inquiry is equivalent to assessing their progress toward the correct answers.

Even in cases which inquiry is valued as a process of developing scientific thinking, there is still no consensus regarding what inquiry exactly entails. For many teachers inquiry is an effective method for learning science “content,” while others emphasize it as a “part of science” and, thus, as a teaching objective of itself (Louca & Zacharia, 2007). When inquiry is the method for learning, it is at best, a valuable teaching tool, more productive than traditional approaches. When inquiry is part of the

science education, then teaching includes helping children to understand its nature and develop abilities to use scientific inquiry effectively for learning, in addition to learning about scientific phenomena themselves. By inquiry, we refer to the “activities of students in which they develop knowledge and understanding of scientific ideas,” as well as an understanding of how to study the natural world (NAS, 1996, p. 23). To offer a more specific definition, we take inquiry to mean the pursuit of causal, coherent explanations of natural phenomena (Hammer, 2004). This may include a variety of classroom-based forms of inquiry, both activity-based (e.g., designing experiments and controlling variables, collecting and interpreting data and observations from physical phenomena) and discourse-based (e.g., using data or observations to engage in argumentation, engage in mechanistic and analogical reasoning).

The definition of children’s inquiry that we adopt for this study suggests the relationship between inquiry as activity, and inquiry as discourse. In fact, from a sociolinguistic perspective (Carlsen, 1991), educational research has stressed the instructional functions of classroom-based inquiry in science as a means for facilitating the construction of scientific knowledge (Solomon, 1994) and supporting children’s abilities for scientific reasoning (e.g., May, Hammer, & Roy, 2006; Russ, et al., 2008). Following this, a growing body of research has developed an interest in classroom discourse (e.g., Abell, Anderson, & Chezem, 2000; Cazden, 2001; Edwards & Westgate 1994; Hogan, 1999; Kelly & Crawford, 1997; Lemke, 1990) for its relevance to children’s inquiry (Hammer, 1995; van Zee, 2000; van Zee & Minstrell, 1997), for the development of student ideas in science (Mortimer, 1995), and for students’ conceptual and cognitive development (Sprod, 1998). By this, it is important to differentiate between children’s inquiry (both activity and discourse-based) and non-focused exploratory talk. We define discourse-based inquiry to include not only knowledge claims and ideas, but also children’s reasoning and inquiry processes (Chin, 2006) such as children’s questions and comments, and children’s epistemologies or experiences used to support their ideas or thinking (Louca, Tzialli & Zacharia, 2012).

The teachers’ role in inquiry-based teaching

Studies investigating teacher practices (e.g., Boulter & Gilbert, 1996; Chin, 2006), have emphasized the teacher’s role as a key factor in promoting and supporting inquiry in the classroom. Among other things, current science education reform efforts stress the creation of classroom environments in which teachers make pedagogical decisions in the midst of instruction, for which they are expected to listen carefully to children’s ideas and adapt teaching instruction based on the ideas and reasoning that children raise (Smith, 1996). Thus, inquiry-based teaching involves a rather complex process of adjusting teacher questioning based on the evaluation of the discussion, to accommodate children’s contributions (van Zee & Minstrell, 1997).

The ability to adapt instruction during teaching requires that teachers are able to notice and respond to aspects of classroom-based children’s inquiry (van Es & Sherin, 2002). To do so, teachers need to be able to listen to their children’s ideas and thinking (van Zee & Minstrell, 1997), identify elements of inquiry, and decide how best to proceed based on an evaluation of what they identified (Louca, Tzialli & Zacharia, 2012). We refer to these abilities as “teacher noticing and responding” (TNR) abilities (van Es & Sherin, 2002). By “noticing” we refer to teachers’ abilities to attend to and reason about children’s inquiry as it takes place during instruction. “Responding” refers to teachers’ abilities to evaluate classroom exchanges and decide which teaching strategy is most appropriate for supporting children’s inquiry.

To this end, teachers need to develop an understanding of how inquiry looks, and refine their abilities to identify and promote children’s inquiry, and respond appropriately from a repertoire of strategies. Such strategies can include teacher questions, prompts, clarifications, evaluations and restatements (e.g., van Zee & Minstrel, 1997; Louca, Tzialli & Zacharia, 2012).

Moreover, time restrictions compound the already challenging work of assessing and responding “instinctively” to in-class student inquiry. Rarely, is there any specific preparation for such skills in PDPs but clearly, the need is great. Teachers need to develop their in-class instincts regarding what they see and respond to with little time for reflection (Louca, Tzialli & Zacharia, 2012). This can only happen by practicing and developing perception and intention through deliberate, explicit reflection as they gain new insights, and adopt a stance of inquiry toward their children's understanding (e.g., Hole & McEntee, 1999; Zeichner & Liston, 1996).

The role of Professional Development

Undoubtedly, developing the TNR abilities depends largely on teachers' initial preparation and subsequent professional development (PD) in teaching science. In particular, it is not sufficient that teachers acquire an understanding of a particular body of knowledge, because children will invariably present ideas not covered in teachers' training. Teachers need to be able to reason about children's ideas, to reflect from the children's perspective on the ideas' merits and liabilities, and to give substantive responses. In order to address this, PD needs to include processes and activities designed to enhance teachers' professional knowledge, skills, expertise and attitudes (Guskey, 2000), seeking to cause qualitative shifts in aspects of teachers' practices (Fraser, et al, 2007). Toward this end, PD can provide teachers with opportunities to refine their content knowledge and teaching pedagogies, understand the need to change, and help them find ways to implement changes in their teaching that will help their students to learn more effectively (e.g., Fishman, Marx, Best, & Tal, 2003; Loucks-Horsley et al, 2003).

Features associated with improved teaching have been identified from a proliferation of research in teachers' PD (e.g., Desimone, 2009; Guskey, 2000). Although multiple ways of organizing these features have been proposed, instead of describing the diverse PD model possibilities, we focus our discussion below on five important features of PD based on prior research. These include (1) the content of the PD; (2) the organization and the structure of the PD activities; (3) the degree of consistency between new experiences provided to teachers and the national standards; (4) the context in which the PD takes place; and (5) the degree to which the activities in PDs emphasize the collective participation of teachers. Our discussion considers the strengths and weaknesses of each PD feature.

The content focus of teacher learning is one of the most influential features of PD (Desimone, 2009) including the overall focus of the PD and which teacher knowledge, skills and experiences are targeted. This can range between focusing on the science content, pedagogical content knowledge and teaching strategies (Carlsen, 1993; Cronin-Jones, 1991; Hollon, Roth, & Anderson, 1991), or a mixture of these (Hill, Rowan, & Ball, 2005; Penuel, et al, 2007). Research suggests a relationship between PD activities focusing on subject matter content as well as how students learn that content with improvements in teacher knowledge, skills, teaching practice and student achievement (e.g., Cohen & Hill, 2001; Desimone, Garet, et al., 2002; Garet et al., 2001).

A second PD feature is the organization and the structure of the PD activities and the ways teachers are engaged in them. Research has found that reform-based PD formats of study groups, teacher networks, mentoring relationships, internships, or teacher research centers (Opfer & Pedder, 2011) are much more likely to lead to sustainable teacher change, than traditional learning formats such as one-off workshops, limited-time courses and conferences, which function more as “style shows” (Ball, 1995; Hawley & Valli, 1999). Moreover, reform activities often take place during the regular school day as part of the process of classroom instruction or during regularly scheduled teacher planning time. On the other hand, research has shown that one-time PD workshops, such as conference and one-or-two day courses, often take place outside the school context, are not typically aligned with ongoing teaching practice, and do not reliably lead to changes in classroom teaching (CTL, 2009; Loucks-Horsley, et al., 1999). Workshop formats of PD are generally criticized for being ineffective in providing teachers with sufficient time, activities, and content necessary to increase their knowledge

and promote meaningful changes in their teaching practices (Loucks-Horsley et al, 1998). Engaging teachers in active learning is also related to the effectiveness of PD (Garet et al., 2001; Loucks-Horsley et al., 1998). Active learning may take a number of forms, such as observing expert teachers or being observed, providing or receiving interactive feedback, and reflecting upon student work (e.g., Banilower & Shimkus, 2004; Borko, 2004; Carey & Frechtling, 1997; Darling- Hammond, 1997).

A third PD feature is the degree of consistency between new experiences provided and the state or national standards and curriculum. Desimone et al. (2002) suggest that productive PD needs to provide teachers with rich and diverse experiences related to the novel ideas on which the PD focuses. The degree of consistency may also be enhanced by incorporating experiences that are consistent with the participating teachers' goals.

A fourth feature is the context of the PD that includes formality, voluntary participation and duration. In more formal contexts, a PD can be made available through external expertise in the form of courses, workshops or formal qualification programs, or alternatively through more informal forms that may include collaboration at school or teacher level, both within or across schools (Gaible & Burns, 2005; OECD, 2009). Another aspect of context is the choice of participation. Participants who volunteer differ from teachers required to participate, in terms of their motivation to learn, their commitment to change, and their willingness to be risk takers (Loughran & Gunstone, 1997; Supovitz & Zief, 2000) and subsequently, this impacts results of the PDs (Yamagata-Lynch, 2003). Additionally, the needs of volunteers and non-volunteers may differ substantially (Lawless & Pellegrino, 2007). When teachers volunteer to participate in PD programs, the expectations and requirements for work related activities increase (Yamagata-Lynch, 2003). Finally, research suggests that teachers need time to develop, absorb, discuss, and implement new practice and knowledge (Garet, Porter, Andrew, & Desimone, 2001), relating to both the span of time over which the PD activities are spread and the number of hours spent in the PD activities (e.g., Cohen & Hill, 2001; Desimone, 2009; Garet, et al, 2001; Opfer & Pedder, 2011). Once teachers begin to apply new knowledge and skills to their practice short PD programs usually offer only a limited follow-up (Penuel, et al., 2007), fail to meet the ongoing pedagogical needs of teachers and are rather disconnected from day-to-day teaching practice (Gross, Truesdale, & Bielec, 2001).

A fifth PD feature is the degree of collective participation of teachers in PDPs. Research suggests that PD is more effective in affecting teacher learning and practice if teachers from the same school, department, area or student grade-level participate collectively (e.g., Desimone et al., 2002; Garet et al., 2001; Wayne et al., 2008). Change in teaching behavior then becomes an ongoing and collective responsibility (Cochran-Smith & Lytle, 1999; McLaughlin & Talbert, 1993; Opfer & Pedder, 2011; Thomas et al, 1998) and can be enhanced by extending collaboration between teachers, school-based teacher mentors, university researchers and curriculum developer mentors (Gerard, et al. 2011). The role of the PD facilitator is also crucial (Borko, 2004). The support for teachers to clarify ideas and reflect on practice depends on the expertise of the mentor or collaborator and the time allocated for teachers to work with him/her during the PD program (Cleland, Wetzell, Buss, & Rillero, 1999; Ketelhut & Schifter, 2011; Penuel & Yarnall, 2005; Penuel et al., 2008; Williams, 2008). Furthermore, facilitators must be able to establish a community of learners in which inquiry is valued, and they must structure the learning experiences for that community (e.g., Phillips, 2003; Remillard & Geist, 2002; Strahan, 2003).

Our Professional Development Program

To address these challenges, we developed a PDP aiming to help teachers develop a range of teaching strategies to support children's inquiry, including abilities to plan and to implement inquiry-based science lessons, as well as TNR abilities.

We decided to address this goal within the context of promoting student abilities for the scientific method, one of the three focal areas outlined by the National Curriculum for pre-school science edu-

cation in Cyprus. Most of the teachers had previously participated in PD regarding the National Curriculum aims. In this way, we sought to use this already established teacher knowledge and practice, in order to help them move a step forward towards developing abilities for identifying and responding to children's reasoning. We also aimed at maintaining a high degree of consistency between the National Curriculum and our PDP goals. To allow sufficient time for PD, we designed this PDP to consist of 10 2,5hr meetings from October to May.

To support teacher collective participation, we created a small group of 20 teachers, with the prerequisite that at least two teachers participated in the program from the same school or nearby schools. We then organized the PDP activities in small study groups based on teachers coming from the same schools or school districts to promote the development of an on-going professional culture.

We also focused on an effort to relate theory and practice at multiple levels and ways. We included activities for designing lessons and implementing them in real classes, talking about pedagogical content knowledge and then reflecting on videos of teaching based on those ideas, engaging teachers in doing science themselves and having them engage their own students in similar science content.

Formally defined by Dewey in 1933, one of the most powerful means for PD used in this PDP was that of reflection (Hoffman-Kipp, Artiles & López-Torres, 2003). Reflection, which is defined as the examination of one's situation, behavior, practices, effectiveness and accomplishments, involving active, persistent and careful consideration, speculation and examination of the practitioner's beliefs, knowledge and practice, "seeks to identify, assess, and change the underlying beliefs and assumptions, the theories-in-use, which directly influence actions." (Osterman & Kottkamp, 2004, p. 16). Various researchers have stressed the usefulness of reflection as a tool for improving teaching practice (Hole & McEntee, 1999), helping to understand the complex nature of classrooms (Zeichner & Liston, 1996), make sense of learning experiences (Osterman, 1990), link theory to practice, examine one's own practice in order to improve teaching, and use new evidence to reassess everyday teaching decisions (Valli, 1997), thus essentially helping to relate PDPs with everyday teaching practice (Schön, 1983). There is a range of different types of reflection (i.e., technical reflection, reflection-in and on-action, deliberative reflection, personalistic reflection, and critical reflection; see Valli (1997) for a summary). In our PDP we included activities that supported reflection-on-action in an effort to foster teachers' reflection-in-action: helping teachers develop teaching strategies for identifying children's inquiry, evaluate it and respond to it during teaching, where there is very little time for reflection.

Our PDP has three distinctive parts. Part I introduced teachers to the aspects of scientific inquiry and inquiry-based teaching and learning in pre-school settings. In order to help teachers relate theory with practice, video excerpts from exemplary science lessons were used to illustrate the theoretical points presented. During this part, we also involved teachers in authentic science learning where, for two months, teachers collected, organized and discussed data from the phases of the moon, in order to develop a model explaining how the moon changes phases. In this way, teachers investigated a topic with which they were unfamiliar, engaged in authentic inquiry practices themselves, and reflected upon the characteristics of this authentic inquiry learning, making connections with the theoretical aspects of scientific inquiry.

Part II focused on helping teachers develop and implement inquiry-based lesson plans in pre-school science. This was a collaborative process of discussing, designing, reflecting, and revising lesson plans within the theoretical framework of inquiry-based teaching and learning in science and the National Curriculum for pre-school science education.

Part III involved teachers watching and reflecting on video clips of each other's lessons (based on the lesson plans developed), illustrating children's inquiry and teachers' ways of identifying, interpreting and evaluating children's inquiry. Table 1 outlines the PDP meetings.

Table 1. Outline for the meetings of the PDP.

	Outline of PDP activities
PART I	
Meeting 1	Presentation and discussion of the PDP's learning objectives Discussion about the purposes of teaching science in kindergarten Investigation of the Moon Phases I
Meeting 2	Examination of contemporary trends in teaching and learning science in kindergarten Examination of the National Science Curriculum in Kindergarten Discussion of issues related to the Nature of Science Investigation of the Moon Phases II
Meeting 3	Examination of scientific inquiry as a teaching and learning approach in science education Discussion about teaching science through inquiry Examination of the differences between the theoretical approach of misconceptions and phenomenological primitives Investigation of the Moon Phases III
Meeting 4	Developing abilities for identifying students' inquiry Developing abilities to respond to their students' inquiry Reflect on and discuss their teaching practices
PART II	
Meeting 5	Discussion about the principles of planning a science lesson based on students' inquiry Reconstruction and plan of a science lesson
Meeting 6	Discussion about the importance of experimentation in science education
PART III	
Meeting 7	Watch and reflect on the participants science I
Meeting 8	Watch and reflect on the participants science II
Meeting 9	Watch and reflect on the participants science III
Meeting 10	Discussion about the teacher's role during a science lesson

METHODOLOGY

The PDP was implemented during the academic year 2010-2011, providing 25 hours of instruction and collaboration with 20 participating in-service pre-school teachers. Each participant teacher taught two science lessons: one before the second meeting and another between meeting 8 and 10. These video recorded lessons provided the data for evaluating the effectiveness of the PDP and its impact on teaching practice. The topic of all the initial lessons was the phases of the moon, which none of the teachers had either taught or studied themselves. The deliberate decision to focus on an unfamiliar topic was taken so that teachers could experience authentic inquiry practices themselves, before engaging children in their classes in similar practices on the same topic. The PDP activities concerning the moon phases could not be transferred to pre-school children, thus requiring that teachers develop their own teaching activities of the subject for their classes. Teachers chose the second lesson's topic from the National Pre-School Science Curriculum, collaborating with the first author to revise lessons in order to reflect authentic inquiry practices for children.

Lesson videos and transcripts served as the primary data source and whole-class conversations were analyzed in terms of (a) time spent on teacher and children talk; (b) the percentage of children's inquiry responded to by the teachers related to the total number of elements of children's inquiry we

identified; (c) what the teachers responded to in terms of elements of children's inquiry, and (d) how they responded to those elements.

Analyses (c) and (d) were based on a coding scheme we have developed previously (Louca, Tzialli & Zacharia, 2012). This scheme differentiates what the teacher is responding to, identifying children's (i) knowledge claims, (ii) reasoning and logic, (iii) everyday experiences, (iv) epistemology and (v) the direction of the conversation. The teachers' responses were identified as either (a) prompts, (b) clarifications (c) evaluation of student ideas or (d) restatement of student ideas. Table 2 provides descriptions of the analytic scheme for what the teachers identified and responded to in terms of children's inquiry. Analyses were carried out by the first two authors independently (Cohen's Kappa = 0.84). Differences in the assigned codes were resolved through discussion.

After coding the transcripts and the videos from both lessons and finalizing the analyses, the second author conducted a series of interviews with the teachers participating in the implementation of the PDP, in order to carry out a participant check of the findings of the analyses. The section below includes a description of the findings from the coding-based analysis along with data from the interviews that support those findings.

Table 2. What the teachers identified and responded to in terms of children's inquiry.

Coding Categories	Code Description
Knowledge Claims	The teacher identifies that a child states a knowledge claim (scientifically or non-scientifically accurate); changes his/her knowledge claim during the conversation; states a knowledge claim that is different from other children's knowledge claims; poses a question about a knowledge claim
Logic & Reasoning	The teacher identifies that a child draws an analogy about how different objects/situations/phenomena share similar behavior/characteristics etc in some respects; identifies a dependency between different things/factors; provides evidence in support of a dependency between different things/factors; provides evidence in support of a knowledge claim. The teacher identifies that a child's knowledge claim has an underlying assumption
Experiences	The teacher identifies that a child states everyday life experiences related to the phenomenon under study or that the children do not use experiences related to the phenomenon under study to support their ideas
Conversation	The teacher identifies that a child's conversational contribution is on a topic different from the topic of the conversation so far (off-track); the teacher identifies that a child poses a clarification question about the topic of the conversation; the teacher begins a conversation about a new topic
Epistemologies	The teacher identifies that a child poses a clarification question about the teacher's expectations for the kind/form of answer that children should provide after a teacher's question

FINDINGS

The codings from the initial lessons show teaching practices prior to any impact from the PDP. As Table 3a shows, on average, in 59.8%¹ of the utterances coded, teachers followed the sequence of activities as they had planned, paying little attention to children’s contributions and ideas. Conversely, in 40.2% of the total utterances coded, teachers allowed students’ responses to guide their activities’ sequence. In the second series of lessons, taught towards the end of the program, we found that on average in 42.2% of the utterances coded, teachers followed the sequence of activities they had planned for their lessons, whereas for 57.2% of the total utterances coded, teachers allowed their students’ responses to guide their activities’ sequence. Additionally, the average teacher utterance duration decreased from 16s to 12s and average children utterance duration increased from 5s to 8s. Figure 1, which is an output of the analysis of both lessons from a particular teacher, is indicative of an additional issue. Although changes in the time allocated to student or teacher talk are not significant, the way time is allocated between the teacher and the students has changed significantly. In the first series of the lesson, the children talk was rather fragmented (e.g., time: 7-12 minutes), with the teacher not allowing the children’s conversation to continue freely, but rather frequently “interrupting” the conversation. However, in the second series of lessons (e.g., time: 22-25 and 28-33), the teacher allowed the conversation to roll continuously, with fewer interruptions for responding to individual contributions.

Although these changes are not significant, they might suggest a possible trend suggesting that teachers began to realize the need to allow students space and time to engage in their own inquiry, and follow more closely student leads in the lessons, rather than simply following a pre-defined teaching agenda and activity sequence. A second implication is the possibility that these kinds of changes in teaching practices may require extensive time in order to become established as teaching routines and present significant results.

As table 3b shows, between the first and the second lesson, there was an increase in teachers’ responses to knowledge claims from 67.9% to 81.9%, and in responses to logic and reasoning from 8% to 12.4%, and a decrease in the responses to children’s everyday experiences from 22.6% to 4.5%. During the interviews, all the teachers highlighted the role of children’s ideas in their lessons, and indicated that the PDP helped them see the importance of this role, which, along with the other ideas discussed in the PDP, was used to guide the design and implementation of their lessons. Teachers indicated that after the PDP they were more comfortable providing their students with time and space to talk about their ideas and exchange them with peers, even if those were significantly different from the scientifically accepted ideas or could potentially direct their lesson down a totally different direction.

Table 3a. Comparison of teacher and student talk.

	First lesson	Second lesson
Teacher talk	51.8% (average 16 sec duration)	52.4% (average 12 sec duration)
Student talk	48.2% (average 5 sec duration)	47.6% (average 8 sec duration)

Table 3b. What the teachers responded to.

Teachers responded to:	First lesson	Second lesson
Knowledge claims	67.9% ¹	81.9% ¹
Scientific reasoning and logic	08.0% ¹	12.4% ¹
Everyday experiences	22.6% ¹	04.5% ¹
Epistemologies	00.0% ¹	00.0% ¹
The direction of the conversation	01.5% ¹	01.2% ¹

¹ Percentages reflect the relative times that the teachers, on average, responded to different aspects of children’s inquiry

Table 3c. How the teachers responded.

Teachers responded by:	First lesson	Second lesson
Prompting	35.3%	37.8%
Making clarifications	36.9%	16.7%
Evaluating	12.4%	38.0%
Restating students' ideas	15.4%	07.5%

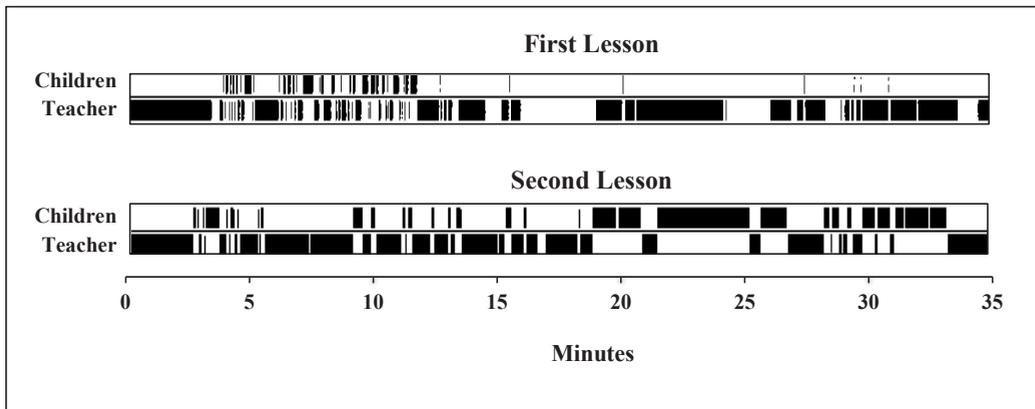


Figure 1. An example of the analysis of the two lessons from the same teacher.

As table 3c shows, between the first and the second lesson, there was a change in the ways teachers responded to their children's inquiry. Although there was not a significant change in the amount of prompting used by the teachers (35.3% in the first lesson and 37.8% in the second), there was a decrease in making clarifications (36.9% in the first lesson and 16.7% in the second), an increase in evaluating their children's ideas (12.4% in the first lesson and 38% in the second), and a decrease in restating their children's ideas (15.4% in the first lesson and 7.5% in the second). Also, as Figure 1 suggests, there was an increase in the second lesson of children's contributions to the flow of the lessons.

During their interview, teachers indicated their anxiety associated to the first lesson they taught, which was a lesson about the phases of the moon that they never taught before. In most of the cases, teachers seemed to suggest that the lack of experiences they had of authentic classroom-based inquiry seemed to make them uncomfortable teaching something new because they were "not sure how inquiry in this lesson would look," in what forms it would appear and how they should respond. However, they all indicated that the second lesson, which they individually decided to teach, was a lesson that they had taught several times, and considered to be very successful. We suggest that this might explain their increased emphasis on knowledge claims in the second lesson – for which teachers thought that they knew enough about to teach it. On the other hand, the emphasis in children's experiences in the first lesson seemed to be related to teachers' adopting a stance of being a part of the learning community and seeing their role as learning along with the children in their class. Not knowing the scientifically acceptable answer might have helped them focus on prompting for and using the children's experiences to construct new ideas that could help explain the phenomenon under study.

Overall, a major impact of the PDP was the refinement of the teachers' abilities to focus their attention during teaching towards children's inquiry. After the PDP, teachers stated that they were in a position to make changes to particular activities in their lessons, focusing particularly on abilities related to scientific inquiry beyond abilities of the scientific method, such as children's abilities to compare and contrast empirical evidence, use analogies to explain new phenomena, and describe the mechanism underlying a particular phenomenon.

DISCUSSION

The purpose of this small-scale study was to describe a PDP we designed for pre-school teachers for teaching science. We have framed this study in the premise of teaching science in pre-school through inquiry (EC, 2007; NRC, 2007; 2011), which includes a variety of classroom-based forms, both activity- and discourse-based. In this view, the teacher's instructional agenda is to support children to engage in that pursuit for themselves, in whichever form, whether experimental or theoretical. Focusing on this teaching agenda, our goal in the PDP was to help a group of pre-school teachers developing their abilities to identify, evaluate and respond appropriately to children's in-class inquiry (Scott, 1998; Louca, Tzialli & Zacharia, 2012). Starting from the literature related to teacher PD (Desimone, 2009; Guskey, 2000), we have identified five key features for teacher PD, which we used to develop the PDP.

Towards this goal, we engaged teachers in a collaborative reflective process (feature 5: teacher collaboration) of making connections between current theoretical constructs of teaching and learning in science, national curriculum and their own teaching practice (feature 3: consistency) specifically focusing on monitoring children's inquiry and progress in the science classroom (feature 1: PD content), through the development, implementation and reflection upon inquiry-based lessons in science (feature 2: PD structure and activities & feature 4: PD context). Then, we described findings from the implementation of this PDP to illustrate how a group of teachers have begun to develop their sensitivity towards children's in-class inquiry and their own repertoire of responses.

Overall, our findings show that teachers participating in this PDP began to pay more attention to children's discourse in their classroom, by talking less, and allowing children to discuss their ideas with peers more freely, suggesting that our PDP can help teachers invoke silence and allow children to "talk" science more productively (van Zee & Minstrel, 1997). This is further supported by the fact that during the second series of lessons, the teachers refrained from evaluating children's ideas and reasoning; rather they clarified children's reasoning and ideas, possibly in an effort to make those ideas more accessible to the rest of the class. Of course, these changes in teacher strategies were not significant, possibly suggesting that they might require longer time periods to take place. This also suggests a possible need for longitudinal studies of teacher changes over a longer period of time, to better investigate how teachers implement these changes and relate them with their teaching experiences.

Findings also indicate that the PDP helped teachers develop their abilities to notice and respond to children's inquiry (Louca, Tzialli & Zacharia, 2012). We are not suggesting that teachers were unable to do so at the beginning of the PDP. In fact, findings suggest that they responded to some of the children's inquiry prior to the PDP. However, after the PDP they were better able to respond more specifically to children's inquiry (e.g., addressing student scientific reasoning) and differentiate their responses based on the content of children's contributions.

On the other hand, we do not suggest that at the end of the PDP implementation teachers were experts in responding to children's in-class inquiry. Although some of the teachers indicated their need to learn more about particular phenomena addressed by the National Curriculum for pre-school science, they all indicated their need for more elaborate critical discussions (and more critical friends) about their taught lessons in order to reflect on what they identified in the children's inquiry and the ways they responded to that inquiry. This possibly suggests a further need for PDPs that would provide pre-school teachers in Cyprus with more experiences of authentic scientific inquiry, so that they could view its multiple facets and forms. Additionally, this suggests a need for collaboration between teachers themselves and researchers, in ways that would enable more extensive collaboration – probably following a school basis model that is completely absent from the Cyprus Education System (Karagiorgi & Symeou, 2007).

A possible weakness of this study is related to the fact that the comparison of the teacher-children talk was carried out between two sets of lessons, which had an important difference. The first lesson was on a topic that was completely new to the teachers (phases of the moon), which none of the teachers had been taught in the past and for a topic which all the teachers felt that they did not have a well-developed body of scientifically accepted knowledge. The second lesson chosen by each teacher, in almost all cases was a lesson that they had taught in the past (usually more than once) and thus, felt comfortable teaching. Although this issue poses a possible methodological limitation of this study, it also raises several interesting hypotheses that might be useful to investigate. As data show, it is possible that being comfortable with a topic in terms of knowing the correct answers, may mislead teachers in focusing their responses on children's ideas towards the knowledge claims stated in the conversation and not on the children's everyday experiences that could be used as building blocks for knowledge claims. For instance, teachers may respond in various ways to children's discourse, by focusing on the content (knowledge claims), the reasoning behind it, or the experiences students use to support their knowledge claims. This also raises a need for further study: does teaching an unknown topic and thus learning alongside the children in their class lead to a more epistemologically correct lesson in science? Alternatively, in what ways do learning science content help pre-school teachers implement more authentic science lessons?

Lastly, findings suggest a wide need for detailed studies about teacher cognition, in particular for the development of TNR abilities (van Es & Sherin, 2002). Significantly, this has faced considerable challenges due to the on-going and complex nature of teaching. Research has shown that experienced teachers may engage in these practices already, while TNR abilities in classroom interactions is something that is perceived as developing over time (Berliner, 1994). In order to better support this development, further studies are needed for investigating how teachers develop TNR abilities.

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¹ Percentages reported in findings are counts of the number of utterances. The mean duration of the utterances are presented in seconds.

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