J Sci Teacher Educ (2012) 23:159–175
DOI 10.1007/s10972-011-9251-2

Elementary Teacher's Conceptions of Inquiry Teaching: Messages for Teacher Development

Joseph E. Ireland · James J. Watters · Jo Brownlee · Mandy Lupton

Published online: 16 September 2011

Abstract This study explored practicing elementary school teacher's conceptions of teaching in ways that foster inquiry-based learning in the science curriculum (inquiry teaching). The advocacy for inquiry-based learning in contemporary curricula assumes the principle that students learn in their own way by drawing on direct experience fostered by the teacher. That students should be able to discover answers themselves through active engagement with new experiences was central to the thinking of eminent educators such as Pestalozzi, Dewey and Montessori. However, even after many years of research and practice, inquiry learning as a referent for teaching still struggles to find expression in the average teachers' pedagogy. This study drew on interview data from 20 elementary teachers. A phenomenographic analysis revealed three conceptions of teaching for inquiry learning in science in the elementary years of schooling: (a) The Experience-centered conception where teachers focused on providing interesting sensory experiences to students; (b) The Problem-centered conception where teachers focused on engaging students with challenging problems; and (c) The Question-centered conception where teachers focused on helping students to ask and answer their own questions. Understanding teachers' conceptions has implications for both the enactment of inquiry teaching in the classroom as well as the uptake of new teaching behaviors during professional development, with enhanced outcomes for engaging students in Science.

J. E. Ireland (✉) · J. J. Watters · J. Brownlee · M. Lupton
Queensland University of Technology, Brisbane, Australia
e-mail: Joe@drjoe.id.au

J. J. Watters
e-mail: j.watters@qut.edu.au

J. Brownlee
e-mail: j.brownlee@qut.edu.au

M. Lupton
e-mail: Mandy.lupton@qut.edu.au

Keywords Inquiry based learning · Primary science · Phenomenography · Student engagement · Elementary science

Introduction

High quality science education is a priority internationally (National Science Board 2007). Governments worldwide recognize the contributions a rich science education provides for their citizens (Abd-El-Khalick et al. 2004; Minner et al. 2010). The National Research Council of America (NRC 2000) speaks of scientific inquiry, and teaching practices that are designed to engage students through inquiry, as such:

> Inquiry is a set of interrelated processes by which students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a right understanding of concepts, principles, models and theories. Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. Students then will learn science in a way that reflects how science actually works. (p. 214)

Internationally, calls are being made to include inquiry learning as part of the curriculum (Lunetta et al. 2007). "Inquiry-based laboratory investigations at every level should be at the core of the science program and should be woven into every lesson and concept strand." (National Science Teachers Association (NSTA) 2007). In order to provide a learning environment in which students are able to engage in inquiry, teachers are required to have an understanding of what scientific inquiry learning is and what pedagogical practices are necessary to help achieve it in students. Although much has been written in support of practices that foster inquiry learning, many researchers feel it is yet to be applied extensively in the average teacher's daily practice (Asay and Orgill 2010; Goodrum et al. 2001). Furthermore, research indicates that its actual implementation in schools is problematic (Abd-El-Khalick et al. 2004; Justice et al. 2009). Although various forms of inquiry such as 'open' or 'guided' inquiry are advocated in the literature (Martin-Hansen 2002), there is limited research on what practicing teachers understand is necessary in their teaching practices to achieve effective inquiry. This study adopts a phenomenographic approach to explore teachers' understandings of teaching for inquiry learning in science, abbreviated herein as *inquiry teaching*.

Background

Given national and international investment in inquiry teaching outcomes, it is important to understand how teachers understand teaching for inquiry learning in science education. One approach the science education community has taken has been to explore the influence of teachers' knowledge on their enactment of inquiry in the classroom. This has been in terms of understanding teachers' conceptions or "ways of experiencing" inquiry teaching (for example, Entwistle et al. 2000). This body of literature is supported by the supposition that teacher understanding of inquiry teaching has an influence on teacher practice (Åkerlind 2004; Ho 2001). By understanding this form of teacher knowledge, a better awareness of its influence in teacher practice may be constructed. For some time now, a considerable amount of research that is focused on teacher knowledge has been undertaken to gain a greater understanding of teachers' conceptions of inquiry teaching (for example, Kember 1998; Lotter et al. 2007). This research has been reported through two distinct bodies of literature, each with their strengths and limitations.

First, comparative studies seek to explore teachers' understanding of inquiry teaching by comparing teachers' knowledge to models promoted in the literature, derived theoretically, or from the practice of expert teachers. For example, the Harwood et al. study (2006) developed a blended qualitative/quantitative instrument (a card sorting activity) for measuring teacher beliefs of inquiry instruction. This instrument is called the *Inquiry Teaching Beliefs* (ITB) instrument, which was developed from researcher generated statements of what was, or was not, inquiry-based instruction. Although this instrument is a suitable measure for inquiry beliefs against the theoretical perspective of the researchers, it was not able to generate an understanding of the teachers' beliefs from the teachers' perspective. Also, while this study claimed to be based on a phenomenographic theoretical foundation, it did not appear to make use of phenomenographic artifacts such as an outcome space, variation theory, or structure of awareness as prescribed for the methodology (Bowden and Green 2005; Marton 1994).

To further complicate this matter, however, is the consensus within the literature that a single model of scientific inquiry, from which these theoretical models are often based, does not exist (Osborne and Collins 2003). In 2003 Osborne and Collins performed a Delphi study of 23 science education community experts attempted to consolidate understanding of the most important attributes of science and inquiry that the experts felt should be taught in schools. The study developed nine themes which were: (a) scientific method and critical testing; (b) creativity (specifically to help make science education engaging); (c) historical development of scientific knowledge; (d) science and questioning; (e) the diversity of scientific thinking; (f) analysis and interpretation of data; (g) science and certainty; (h) hypothesis and prediction; and (i) cooperation and collaboration in the development of scientific knowledge. Interestingly, the relationship between scientific laws and theories was not explicitly considered in the Delphi study, despite being treated as a core attribute by several studies into NOS (Lederman 1992), such as found in the *Views of the Nature of Science* Questionnaire Version C (VNOS-C, Lederman et al. 2002).

Although theoretical models derived from observations on practice are important in establishing the consensus about the nature of a phenomenon such as inquiry teaching, what teachers do in practice depends on their personal understanding of the phenomenon and the contextual constraints or circumstances influencing their teaching (Keys 2005). It is from these experiences that teachers construct their understandings of inquiry teaching. These studies, although having much to contribute to our understanding of the role of teacher knowledge in inquiry teaching, could be failing to explore the full depth of understanding the phenomenon. Such understanding can be enhanced by exploring the conceptions that teachers have of the phenomenon. The implications of this limitation might explain the inability of many professional development programs to change teacher practices in regards to the teaching science though inquiry because of a failure on the part of teacher educators to understand teachers' conceptions in the first place (Porlán and Pozo 2004; Sandoval 2005). Thus, the call has been made for studies which document teacher thinking or implicit theories rather than those which are "looking for fidelity of implementation" (McDonald and Songer 2008, p. 974).

A second body of literature concerned with understanding teacher knowledge of inquiry teacher does strive to understand the phenomenon of inquiry teaching from teachers' perspectives using individual recounts. However, in spite of their contributions, an important limitation still remains. These studies are typically based on recounts of individual experiences of the phenomenon, implying (and sometimes finding) that there are as many understandings of inquiry teaching as there are teachers trying to implement it (for example, Fazio 2005; Seroussi 2005). For example, in a doctoral study Seroussi (2005) examined the perceptions of teaching approaches that foster student inquiry and influence of teacher beliefs of student learning on the inquiry teaching practices of a group of six teachers in grades 7–12. A mixed methodology was used including semi-structured interviews of both students and teachers (Seroussi 2005), surveys (the teacher version of the CIS—classroom inquiry survey, and the CLIS—Classroom learning environment survey), and observations (two observations over a 3 week period).

Several themes were generated, which the researcher felt summarized two major trends in the data: teachers displayed a continuum of inquiry practices from none to inquiry as regularly integrated with instruction, and that teacher pedagogical practices were related to their beliefs about student learning and beliefs about inquiry (similar, in a sense, to studies on conceptions, e.g. Ho 2001).

The study recommended that further research was required into the influence of teacher beliefs of inquiry learning, and this study may be seen to respond to this recommendation. While the Seroussi thesis highlights several issues related to the implementation of inquiry learning in schools, it again develops as many conceptions of inquiry as there are participants in the study: "In each of the case studies, the teachers have defined inquiry in different ways and have used instruction that is both consistent and inconsistent with their definitions" (Seroussi 2005, p. 82).

Although these studies are powerful in terms of highlighting individual experiences of the phenomenon, they leave open the question of whether the vast diversity among teacher conceptions can be meaningfully reduced to a few key theoretical principles. It is expected that these principles would represent in succinct and parsimonious terms the major differences in the ways that teachers experience and hence understand inquiry teaching. The aim is therefore to distill the essence of teachers' experiences without unnecessarily diluting the diversity of teacher practices and opinions. Phenomenography allows us to do this by qualitatively categorizing teachers reported experiences of the phenomenon of inquiry teaching.

This paper contributes to the theory–practice nexus by using phenomenography to understand the qualitatively different ways in which teachers report their experiences of inquiry teaching. The research question was: What are the qualitatively different ways in which elementary school teachers experience inquiry teaching in science?

Methodology

Phenomenography was chosen as the appropriate research approach for this study (Bowden and Green 2005; Marton 1994). Phenomenography sets out to map a limited range of categories of reported experiences of the phenomenon, called the outcome space. The outcome space relates to the participants experiences as a group, not as individuals, and does so without comparing such experiences to preconceived models (Marton and Booth 1997).

In keeping with phenomenographic techniques (Åkerlind et al. 2005) variation among participants was deliberately sought in order to maximize variation in the data. In the current study this variation was expressed in terms of: gender, years in teaching, school year level taught, school, and previous professional development experience in science teaching. The study was conducted in a large Australian metropolitan city. Participant teachers were drawn from elementary schools with relatively diverse socio-economic status, cultural perspectives and ethnicity. Of the 20 participating teachers (T1–T20), five were male. The teachers had been teaching for a range of 2–30 years, and most had taught in various year levels from preparatory (student age 5) through to Year 7 (student age 12).

In phenomenography the main source of data are semi-structured interviews with participants. Twenty teachers were interviewed for 40 min on average, and interviews transcribed and analyzed in a phenomenographic tradition (Åkerlind 2005). The teachers were asked to respond to semi-structured interview questions that began with the question "Can you tell me about a recent teaching experience you have had in which you feel you taught science through inquiry particularly well?" Participants were free to discuss issues they felt were important, though the interview questions covered the themes of: teachers' role, students' role, role of assessment, goals of inquiry teaching, and outcomes in terms of when teachers knew their approach was working. The interviewer was careful to demonstrate empathy towards participants, and to bracket his own preconceptions during the interview process (Ashworth and Lucas 2000).

All interviews were transcribed verbatim and analyzed for emergent themes. Personal profiles were developed for participants in order to assist in maintaining fidelity to their individual conceptions. This analysis developed through a search for the essential aspects of the experience as revealed from the transcripts, and the categorizing of the limited number of qualitatively different experiences initially in terms of the global meaning the experience held for participants.

Analysis at all stages focused on defining the structure of awareness of the phenomenon for participants (Marton 2000). The structure of awareness is an analytical framework used in phenomenography to identify those components of an experience that the participants focus on as reflections of their experience of the phenomenon. Booth (1997) described the structure of awareness as consisting of the theme, thematic field, and margin of awareness. The theme is the quality that is focal in awareness, such as ‘force’ in a physical sciences question regarding the forces acting on a cyclist. The theme is surrounded by a thematic field of related concepts and ideas that are directly related to the theme such as ‘gravity’, ‘wind resistance’ or ‘reaction force’. The border between theme and thematic field is not one of rigid exclusion, but ideas within the field may become the theme and vice versa depending on the shifting awareness of the individual. The individual is also aware of many things that do not bear relevance to the task at hand, things that “are unrelated to the theme but coexistent with it in space and time” (Marton 2000, p. 113). These are contained in the margin of awareness.

An individual’s way of experiencing a phenomenon is referred to as a conception (Marton 2000). However, the researcher-developed categorizations of those conceptions are known as categories of description (Bowden 2005). A single category of description thus expresses one possible way in which many participants, or the same participant at different times, might experience a phenomenon (Marton and Pong 2005). Although conceptions represent the experiences of the participants, categories of description are the creation of the researcher.

The findings, which in phenomenography are described as an outcome space, are then rigorously examined for their appropriateness through repeated iterations with the data, as well as numerous meetings with the research team, interested peers and through feedback on conceptual papers presented at various education conferences.

Results

The phenomenographic analysis of data revealed three qualitatively different ways in which the teachers in this study experienced teaching for inquiry learning in science education. They are as Student centered experiences (Category 1); Teacher generated problems (Category 2); and Student generated questions (Category 3). These three form a hierarchy with Category 3 being the broadest and most inclusive way of experiencing teaching for inquiry learning by the participants. Each of the categories was found to take a student-centered approach because teachers were more concerned with how students learnt than how teachers taught. In terms of student direction of the learning Category 3 was the most student-centered and Category 1 the least. Category 3 was reported as being used the least by teachers in this study, while Category 1 was experienced by every teacher. Each category was present at all year levels, with no clear preference for a certain category in, say, upper years. An overview of the results are presented in Table 1.

As can be seen from Table 1, the global meaning of the experience for teachers differs between categories, where the experience of inquiry teaching is focused on either giving students interesting experiences (Category 1), challenging their thinking with interesting problems (Category 2), or helping students to ask and answer interesting questions (Category 3). However, as a hierarchical structure of awareness, teachers who described Category 3 did at times provide interesting

Table 1 Outcome space for structure of awareness

Global meaning	Theme (focus of awareness)	Thematic field	Margin
Category 1—Inquiry teaching is experienced as providing stimulating experiences to students	Student centered experiences	Teacher generated problems, Student generated questions	"Chalk and Talk" (transmissive approaches to teaching)
Category 2—Inquiry teaching is experienced as providing challenging problems to students	Teacher generated problems	Student centered experiences, Student generated questions	Inquiry needs to be given depth and context through providing a challenging problem. It's not inquiry if it's just "wow, look at that" experiences
Category 3—Inquiry teaching is experienced as assisting students to ask and answer their own questions	Student generated questions	Student centered experiences, Teacher generated problems	Most inclusive definition, thus also saw "chalk and talk" as belonging outside inquiry teaching

experiences or challenging problems in order to teach. It was noted that, contrary to the expectations of educational theorists, teachers did not make use of the language of educational theory regarding inquiry teaching, specifically with regards to there being levels of inquiry in terms of student and teacher roles (National Research Council of America 2000), or terminology such as *open* or *guided* inquiry (Martin-Hansen 2002).

The curriculum focus described the goals teachers tended to hold for their teaching—either content outcomes such as knowledge of atoms or life cycles, attitudes such as 'science is fun', or science inquiry skills such as posing investigable questions and devising investigations to answer such questions.

Typically, phenomenography does not compare demographic information regarding the number of subjects which experienced each category as their dominant conception. This is because during analysis the interview transcripts are considered as a whole, thus a single category of description may express one possible way in which many participants, or the same participant at different times, might experience a phenomenon (Marton and Pong 2005). However, some readers may find it informative to gain a general sense of the spread of categories among participants. It was found that of the participants, ten experienced Category 1, six experienced Category 2, and four experienced Category 3 as their *predominant but not exclusive* way of conceptualizing inquiry teaching. Participants often expressed diverse conceptions depending on the context. For example, participant 8 experienced inquiry teaching as helping students to ask and answer their own questions in the early childhood context, but when discussing her work in upper primary was very focused on the student *experiencing* content material.

Category 1—Experience-Centered Category

Inquiry teaching was experienced as an Experience-centered conception (Category 1) when teachers structured their teaching around a concern for students' personal experiences during learning, with a focus on sensory events. That is, there was an expectation that the students would see, hear, feel and do interesting things that would focus their attention, have them asking science questions, and improve their engagement in learning. This expectation is illustrated in the following quote:

> Teacher 1 …each day we measured how high our tomatoes were growing and whether they had characteristic fruit on them or not, and the children, …*through their own life experiences* could see that the one that we nurtured, the tomato plant that had the sun, the water, grew, um, higher and healthier than the others. (italics added)

The focus of this category was educating and engaging students through their physical interaction with science in the classroom. In particular, students were engaging with science materials in some way, including cups, strings and tomato plants, as well as more scientific equipment such as thermometers, stopwatches and internet sites. In essence students were exposed to the environment as a stimulus to generate interest and knowledge. The Experience-centered category was seen as fostering inquiry in that students were encouraged to ask questions about the experiences they were having. This perspective acknowledges that scientific ideas are developed through direct experiences, as with the literature on student centered learning (McKenzie 2003).

Examples of teacher practice given by participating teachers during this category included growing tomato plants in various conditions to observe what qualities made them flourish (T1), playing with live worms after reading about them (T5), and watching videos about volcanoes to highlight science content material (T20). Examples also include allowing students unstructured play with equipment during a science lesson (T3, T4, T5), as free choice activities during student's free time (T16), or when teachers teach students how to perform an activity and allow them to re-perform it before school (T6, T9). Scientific proofs, that is, science content demonstrations by teachers or students making use of experimental procedures to obtain expected results, are also seen as belonging to this category (for example, T6).

Encouraging students to ask questions was seen as important, but was not central in teachers' thinking during this category. Thus the role of student questions is seen as belonging to the thematic field of awareness. Student questions were used to help teachers assess student understanding and heighten student engagement in their learning. It can be noted that the role of student questions develops across each category until it becomes focal in Category 3. Teacher generated problems were also occasionally used to help students to experience the content the teacher intended. However, the teacher generated problems in this category tended to be very simple problems requiring straight forward observation of phenomenon, such as requiring students to try and find the worm eggs in the soil (T5), and are for this reason considered in the thematic field of awareness.

Traditional transmissive approaches, or "chalk and talk" (T1), were seen as being in the margin of teacher awareness, or what inquiry teaching was *not*. The focus was on teaching students through engaging them with interesting experiences, as teacher 19 explained;

> Teacher 19 …they're finding things out for themselves and it's more meaningful to them, I think. Like if we try and tell them something they may not remember it. But if they have *done it themselves* that learning is more valuable. (emphasis added)

Some teachers described this as their predominant way of experiencing inquiry teaching (T1, T5, T10, T16, T20), while others used it as one activity among many during a science unit (T2, T4, T7). One teacher in the early childhood curriculum mentioned that this was how she taught "all the time" (T3).

Category 2—Problem-Centered Category

Inquiry teaching was experienced as a Problem-centered conception (Category 2) when teachers structured their teaching around a given problem they designed and that the students were required to solve, as the following quote illustrates;

> Teacher 17: … Usually I begin with a question or a problem or a story and there's a problem in the story that has to be solved. And then we, as a class group, find out how we're going to solve this problem. So it might be through acting it out, it might be making a model … So that's how I see inquiry-based learning, beginning with some sort of question or story …"Well what are you going to do about it?"

As can be seen in T17's comment, the problem is focal in teacher awareness as teachers feel it helps students engage with the topic at hand and produce productive work. As with Category 1, student generated questions were part of the teacher's awareness as supportive of inquiry teaching, but not the focus of it. Thus student questions are part of the thematic field of teacher awareness in this category. Also in the thematic field was the role student experiences played, assisting students to learn and engage but not being the focus of teacher practice and thinking. Unlike Category 1, at the margin of awareness was the notion that student centered experiences, although interesting, were not alone sufficient to make a teaching experience qualify as inquiry. As teacher 16 explains, the experience of the so called 'science experiments' alone is not enough to educate students through inquiry teaching;

> Teacher 16: And so you go out to the supermarket and you get all the things and you grab the random science book and you find experiments that you know you're going to be able to do at school. I find that, yes, while the kids enjoy it-it lacks content. It lacks the depth of learning because each different experiment will cover a different facet of science so it doesn't really get into the how's and why's. It's a bit Professor Sumner Miller.[1] You know it's like "The glass and a half" and they go "Wow" and then that's about it.

[1] Julius Sumner Miller was a popular TV presenter of science shows in the 1960s and 1970s.

Examples of teaching activities in this category include: working out how to lift a heavy box using only a cylinder and plank (T14); responding to an imaginary letter from an underwater theme park for information on how to set up a new exhibit (T18); building a tower using paper and sticky tape that would support a tennis ball (T10); setting students the task to 'find out about natural disasters' (T17) or an undersea animals (T6) from the internet or library. Examples may also include problems that required specific scientific knowledge and materials, such as designing, building and testing energy efficient shoebox houses (T4); testing water absorption into the atmosphere (T15); measuring viscosity, the co-efficient of bouncing, or the hardness of rocks (T7); developing tests to compare towel absorbency (T16), or as part of a broader unit on energy-working out how to light a light (T4).

Category 3—Question-Centered Category

Teachers experienced inquiry teaching as Question-centered (Category 3) when they structured their teaching around helping students to ask and answer their own questions. The students' questions were focal to the teaching experience as teachers saw students as being more motivated and engaged with science content and materials when they were seeking to answer their own questions rather than with traditional teaching methods, as is illustrated in the following quote;

> Teacher 18: To me inquiry learning is giving children the opportunities to find out new things, and to ask the right questions to learn about new things in a collaborative way, and to be able to not just be given the knowledge and stand out the front. I think that's the traditional approach, is that the teachers stand there and give the children the knowledge that they're expected to know. Whereas inquiry is taking it to that other side, where the children find out what it is that they want to know, and we give them the tools to be able to do that.

Significantly for this category the is emphasis placed on enabling students to explore phenomena for their own sake, for instance captured by the statement that "children find out what it is that they want to know." Focal in teacher awareness is the role student generated questions plays in inquiry teaching, and in helping students understand and enjoy science. Student centered experiences and teacher generated problems were seen as supportive of this focus, thus existing in the thematic field of awareness. In this category, teacher generated questions do not constitute student inquiry, as teacher 2 explained "children are posing questions, and formulating ways to answer that question", while teacher 8 believes that "I just think if you're doing an inquiry they're (students) inquiring into things and posing questions and trying to answer questions." Also, when asked to define the related concept of inquiry learning, teacher 16 explained "being allowed to explore at your level to answer your *own* questions," which may be taken to exclude exploring at your own level to answer the *teacher's* questions. It can be assumed, therefore, that a curriculum based on teacher generated questions would be considered as outside inquiry teaching or at best, a Problem centered experience (Category 2).

As with Category 1 some teachers saw inquiry through a focus on students posing questions as the way they teach all the time, again exclusively in an early childhood setting (T6, T8). Other teachers reported that inquiry was only one way among many ways of teaching (T4, T2). Typically, Category 3 defined an entire unit of work in science, while Categories 1 and 2 often designated specific activities teachers designed for students but as part of a broader suite of practices in science.

Examples of teaching activities in this category include negotiating a topic with students, such as; "under the sea" (T6) or "micro beasts" (T8), then organizing students to generate questions and research their answers within that topic. This category also includes scientific investigations where the teacher selects the topic and helps students to generate and answer their own questions in relation to that topic. Examples include developing a way of testing advertising claims for superior products (T4), or exploring the qualities of successful balloon rockets (T2). In any situation, the focus is on helping students to ask and answer their own questions.

Discussion

The three conceptions of inquiry teaching which emerged in the study were; (a) The Experience-centered conception where teachers focused on providing interesting sensory experiences to students; (b) The Problem-centered conception where teachers focused on challenging students with engaging problems; and (c) The Question-centered conception where teachers focused on helping students to ask and answer their own questions. A major contribution of this study was to document the range of conceptions of teachers who engage their students in inquiry based learning in science, and thus provide input into the conceptions that teachers hold about inquiry teaching. Knowing how teachers experience inquiry teaching, as opposed to teachers' reported 'theories in use' (Argyris and Schön 1974), is one of the most valuable contributions of this study to the literature. One limitation of this study is that it effectively is only a verbal response by teachers of what they say inquiry teaching is. This study also does not compare teacher conceptions with student outcomes, or even reported conceptions with actual teacher practice. However, teacher conceptions are expected to serve as indicators of teacher practice (Åkerlind 2004), as well as moderate the uptake of new and more effective teaching behaviors (Porlán and del Pozo 2004; Prosser et al. 1994), for example, during professional development.

The results of this study are now situated in the broader context of science teacher education. Table 2 compares the results of this study with the NRC (2000), Martin-Hansen (2002) and Bybee's 5E's (2001) descriptions of inquiry teaching.

Many points of congruency may be found between the current study and the studies cited, for instance, some similarity exists between Category 2 and each of the studies (Bybee 2001; Martin-Hansen 2002; National Research Council of America 2000). In other ways, there are clear mismatches between the studies. The Martin-Hansen (2002) model is fairly similar, with each category from this study matching on to a level of the Martin-Hansen model. However, the Martin-Hansen

Table 2 Comparison of results with some major theoretical models of inquiry

Current study	NRC of America (2000) From less (level 1) to more (level 4) teacher direction	Martin-Hansen (2002) Open (full), coupled, guided, structured (closed)	5E's, Bybee (2001) engage, explore, explain, elaborate, evaluate
Experience-centered category	Most similar to level 4 teacher directed, however, students may have been encouraged to gather own evidence and conclude on it from their own experiences (albeit pending teacher approval)	Structured inquiry relates strongly to Category 1, however, Experience-centered inquiry is more student centered than the "following recipes" description of structured inquiry in the Martin-Hansen text	Both Categories 1 and 2 fit very well within the 5E's model
Problem-centered category	Category 2 relates to Level 2 (and somewhat 3), though they may have been told how to analyze data	Guided inquiry matches well with Category 2—both focus on having the teacher select topic and challenge students to answer teacher generated questions	Both Categories 1 and 2 fit very well within the 5E's model
Question-centered category	Category 3 of this study corresponds well with Level 1 in terms of students identify and posing questions, however students may not have been given data and told how to analyze	Open or full inquiry (also, the open inquiry section of Coupled inquiry) match reasonably well with Category 3—however the Martin-Hansen paper does not explicitly allow for material-less inquiry such as library search	Category 3 is not seen in the 5E's model in as much as student questions do not guide the teaching: At all times a challenge or experience as designated by the teacher guides the teaching

model does not explicitly allow for inquiry that does not require science equipment and materials, such as library search, as this study does.

The theoretical model of the NRC (2000) is found to present a mismatch in terms of teacher understanding and terminology. When teachers are experiencing inquiry teaching as Category 1 as per this study, the role of the question may be level 4 teacher directed as per the NRC definition. However, at the same time the role of evidence and attending explanations is found to be more appropriate to level 2 in the NRC—teachers are striving to help students decide or discover content material from their own experiences. Knowing teacher understanding in terms of these qualities is one of the great advantages of this study over theoretically derived definitions.

The 5E's model (Bybee 2001) was found to be lacking in that while student questions are valued and encouraged, at no point does the model explicitly consider that such questions could guide and structure the inquiry teaching experience. While students may often select a problem during the elaborate phase, questions are not guiding the teaching experience. In this manner, Category 3 ways of experiencing inquiry teaching are potentially absent from the 5E's model of inquiry teaching. This absence leads us to ask if the 5E's model is limited in the following way—if authentic inquiry is taken as structuring teaching around student generated questions, as in Category 3 of this study, is the 5E's model, while engaging, failing to emulate authentic inquiry if it does not explicitly solicit and explore student questions during the teaching experience?

These comparisons continue to illustrate that curriculum documents and educational theory are somewhat at odds with the actual teacher conceptions of inquiry teaching as found in this study. Perhaps this disparity is made most clear by the fact that teachers did *not* make use of educational theorist terminology in reference to their actual work. Terms such as *open*, *guided* and *free* inquiry (Martin-Hansen 2002) were not part of teacher vocabulary when discussing their practice of inquiry teaching in the classroom. Also, teachers' understanding was not influenced by the idea of different kinds or levels of inquiry teaching (for example, simple or authentic)—teachers spoke about their work as being inquiry teaching or not: there were no levels in teacher language. These points indicate that, at least with every teacher in this study, such models of inquiry have not yet had a lasting effect on the meaning and language teachers used to describe their conceptions of inquiry teaching. The purpose of this study has been to find out what language and ideas *are* being used by teachers, as part of their conceptions of inquiry teaching.

The first category aligns with a purpose of fostering an inquisitive habit of mind through strategies that implicitly indicate an acceptance of constructivist approaches to learning. That is, by actively engaging students with a natural phenomenon though which materials are manipulated and ideas are explored in a social context a deeper understanding of and disposition towards learning science is achieved. However, the assumptions held by those teachers experiencing this conception of inquiry teaching aligns only marginally with principles of student centered learning and ignores the role that teachers play as scaffolders of learning. For instance there is at times a minimal consideration of the purposes of engaging students in learning tasks, of deeper critical thinking around the phenomenon or explicit instructional practices to scaffold learning. These principles underpin effective teaching strategies for student centered learning environments (e.g., Dennen 2004; McCombs 2003). This conception often represents a "hands-on" perspective which has been critiqued as failing to provide engagement of the young mind in science (e.g., Wheeler 2000).

The second category is where the focus moves to providing opportunities for student inquiry through the provision of problems that linked with the curriculum. The teaching approach is focused more on incorporating scaffolding strategies around students solving specific problems. Those teachers adopting this approach are seen to be attempting to help students make sense of a phenomenon and provide opportunities for sharing those experiences by a focus on teacher defined questions. However, there is an expectation that there will be a scientifically mandated outcome. The approach aligns with Joseph Schwab's (1960) notion of stable inquiry through which students come to understand canonical science, "by stable inquiry I mean researchers which receive their conceptual principles from others and treat these principles as matters of fact, not matters for test" (p. 181).

The third category extends conceptions of inquiry teaching to include what Schwab might have described as "fluid inquiry" and which underpins contemporary perspectives of science as inquiry (National Curriculum Board 2009; National

Research Council of America 2000). Through this practice teachers strived to help students to be able to identify questions, design and implement investigations and formulate explanations in which argument is based on evidence. As Alberts (2000), from the perspectives of a practicing scientist, argued "What I mean by teaching science as inquiry is, at a minimum allowing students to conceptualize a problem that was solved by a scientific discovery, and then forcing them to wrestle with possible answers to the problem before they are told the answer" (p. 4). This approach to inquiry teaching was almost realized in this study, however, teachers fell short of the ideal of allowing students to conclude on the basis of their own analysis and reason when their conclusions were at odds with canonical science, thus again falling short of constructivist ideals where students can be treated as creators, and not merely consumers of knowledge. Category 3 in this study is conceptualized as the broadest way in which a teacher can experience inquiry teaching, and as the most likely conception to be receptive to inquiry as it is promoted by theoretical standards. While many examples of excellent conceptualization of science teaching exist, particularly in Category 3, not all teachers experienced inquiry teaching as being driven by student generated questions.

The findings that conceptions of inquiry teaching range from relatively naïve approaches to sophisticated strategies reinforces the concern that despite considerable professional development, curriculum mandated practices, and public assessments that emphasize students being scientifically literate and able to engage in investigations in science, that much work remains to be done.

The results raise implications for both practicing and preservice teacher education programs. For example, these results provide teacher educators with insight into the understandings that preservice and practicing teachers could bring with them to professional development, especially as new science curricula are implemented which might challenge pre-existing conceptions (Porlán and Pozo 2004; Sandoval 2005). If, for instance, a teacher conceives of inquiry teaching as essentially giving students challenging problems, teachers may be expected to mold professional development initiatives to fit this conception rather than actively confronting their perceptions and altering their conception of inquiry teaching itself. They may see a program of soliciting student questions for exploring circuit work as part of a process that engages students, rather than a key strategy in helping students to become inquirers. In Category 2, the role of student questions is used only to indicate student engagement rather than fulfilling the potential of directing student learning.

As another example, if a teacher's conception of inquiry teaching is about engaging students through interesting sensory experiences (Category 1), efforts to change teacher practice through professional development programs to more student-centered authentic inquiry (Category 3) might fail because to such a teacher, new activities are judged valuable if they promote student engagement, and not because they help students learn how to ask and answer their own questions. The questions students ask will be given the role of focusing student attention and indicating student interest, rather than being the focus of what a student may learn. Whether teachers are attempting to enact either an open, guided, or coupled inquiry (See Martin-Hansen 2002), teachers will be looking for pedagogical activities that will engage students through interesting experiences, rather than helping students to develop a rich conception of science though asking and answering their own questions.

It is recommended that preservice and practicing teachers be given opportunities to experience inquiry teaching from the perspective of the different categories in order to broaden and challenge their thinking. One practical strategy would be to have teachers design and deliver inquiry lessons based on the three categories. Another would be to present case studies of practice and have teachers analyze the approach from the perspective of the three categories. These activities may help teachers to move towards more student-centered, authentic inquiry learning outcomes for their students and themselves. Furthermore, providing a range of experiences with inquiry teaching may help teachers to see examples of inquiry in practice for themselves, which may have a reciprocal effect on teacher conceptions.

With the situation of under-implementation of inquiry teaching in schools, studies continue to explore reasons why this method is not being used. This study has found that some teachers' conceptions are not congruent with the most expansive way of experiencing inquiry teaching found in this study. This study indicates that inquiry teaching can be seen as more than helping students to solve problems as is the focus during problem based learning (Bennett and Holman 2002), and more than helping students experience science as per the discovery learning movement (Kowalczyk 2003). Pedagogical practices that hope to achieve the greatest outcomes for students through inquiry teaching should look beyond motivating students through interesting experiences, and beyond challenging them with teacher generated problems, to actually scaffolding students in the asking and answering their own questions.

References

Abd-El-Khalick, F., Baujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., et al. (2004). Inquiry in science education: International perspectives. *Science Education, 88*(3), 397–419.

Åkerlind, G. (2004). A new dimension to understanding university teaching. *Teaching in Higher Education, 9*(3), 363–375.

Åkerlind, G. (2005). Variation and commonality in phenomenographic research methods. *Higher Education Research and Development, 24*(4), 321–334.

Åkerlind, G., Bowden, J. A., & Green, P. (2005). Learning to do phenomenography: A reflective discussion. In J. A. Bowden & P. Green (Eds.), *Doing developmental phenomenography* (pp. 74–100). Melbourne: RMIT University Press.

Alberts, B. (2000). Some thoughts of a scientist on inquiry. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 3–13). Washington, DC: American Association for the Advancement of Science.

Argyris, C., & Schön, D. A. (1974). *Theory in practice: Increasing professional effectiveness*. San Francisco: Jossey-Bass.

Asay, L. D., & Orgill, M. (2010). Analysis of essential features of inquiry found in articles published in The Science Teacher, 1998–2007. *Journal of Science Teacher Education, 21*(1), 57–79.

Ashworth, P., & Lucas, U. (2000). Achieving empathy and engagement: A practical approach to the design, conduct and reporting of phenomenographic research. *Studies in Higher Education, 25*(3), 295–308.

Bennett, J., & Holman, J. (2002). Context-based approaches to the teaching of chemistry: What are they and what are their effects? In J. K. Gilbert (Ed.), *Chemical education: Towards research-based practice* (pp. 165–184). Dordrecht, The Netherlands: Kluwer Academic.

Booth, S. (1997). On phenomenography, learning and teaching. *Higher Education Research and Development, 16*(2), 135–158.

Bowden, J. (2005). Reflections on the phenomenographic team research process. In J. Bowden & P. Green (Eds.), *Doing developmental phenomenography*. Melbourne: RMIT Publishing.

Bowden, J., & Green, P. (2005). *Doing developmental phenomenography*. Melbourne: RMIT University Press.

Bybee, R. (2001). Constructivism and the 5E's (Publication. Retrieved March 2, 2010. http://www.miamisci.org/ph/lpintro5e.html).

Dennen, V. P. (2004). Cognitive apprenticeship in educational practice: Research on scaffolding, modeling, mentoring, and coaching as instructional strategies. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 813–828). Mahwah, NJ: Lawrence Erlbaum Associates.

Entwistle, N., Skinner, D., Entwistle, D., & Orr, S. (2000). Conceptions and beliefs about "good teaching": An integration of contrasting research areas. *Higher Education Research and Development, 19*(1), 5–26.

Fazio, X. E. (2005). *Exploring teachers' beliefs and knowledge about scientific inquiry and the nature of science: A collaborative action research project*. Unpublished doctoral dissertation, University of Toronto, Canada.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Canberra: Department of Education, Training and Youth Affairs.

Harwood, W. S., Hansen, J., & Lotter, C. (2006). Measuring teacher beliefs about inquiry: The development of a blended qualitative/quantitative instrument. *Journal of Science Education and Technology, 15*(1), 69–79.

Ho, A. S. P. (2001). A conceptual change approach to university staff development. In D. Watkins & J. B. Biggs (Eds.), *Teaching the Chinese learner: Psychological and instructional perspectives* (pp. 237–252). Melbourne: Comparative Education Research Centre.

Justice, C., Rice, J., Roy, D., Hudspith, B., & Jenkins, H. (2009). Inquiry-based learning in higher education: Administrators' perspectives on integrating inquiry pedagogy into the curriculum. *Higher Education, 58*(6), 841–855.

Kember, D. (1998). Teaching beliefs and their impact on students' approach to learning. In B. Dart & G. Boulton-Lewis (Eds.), *Teaching and learning in higher education* (pp. 1–25). Melbourne: Acer Press.

Keys, P. M. (2005). Are teachers walking the walk or just talking the talk in science education? *Teachers & Teaching, 11*(5), 499–516.

Kowalczyk, D. L. (2003). *An analysis of K-5 teachers' beliefs regarding the uses of direct instruction, the discovery method, and the inquiry method in elementary science education*. Unpublished doctoral dissertation, Indiana University Pennsylvania.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331–359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of the nature of science questionnaire: Towards a valid and meaningful assessment of learners' conceptions of the nature of science. *Journal of Research in Science Teaching, 39*(6), 509.

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching, 44*(9), 1318–1347.

Lunetta, V. N., Hofstein, A., & Clough, M. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In N. Lederman & S. Abell (Eds.), *Handbook of research on science education* (pp. 393–441). Mahwah, NJ: Lawrence Erlbaum.

Martin-Hansen, L. (2002). Defining inquiry: Exploring the many types of inquiry in the science classroom. *The Science Teacher, 69*(2), 34–37.

Marton, F. (1994). Phenomenography. In T. Husen & T. N. Postlethwaite (Eds.), *International encyclopaedia of education* (2nd ed., Vol. 8, p. 4424). London: Pergamon.

Marton, F. (2000). The structure of awareness. In J. Bowden & E. Walsh (Eds.), *Phenomenography* (pp. 102–116). Melbourne: RMIT University Press.

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Erlbaum.

Marton, F., & Pong, W. Y. (2005). On the unit of description in phenomenography. *Higher Education Research and Development, 24*(4), 335–348.
McCombs, B. L. (2003). A framework for the redesign of K-12 education in the context of current educational reform. *Theory into Practice, 42*(2), 93–101.
McDonald, S., & Songer, N. B. (2008). Enacting classroom inquiry: Theorizing teachers' conceptions of science teaching. *Science Education, 92*, 973–993.
McKenzie, J. (2003). *Variation and change in university teachers' ways of experiencing teaching*. Unpublished Doctoral dissertation, University of Technology, Sydney.
Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474–496.
National Curriculum Board. (2009). Shape of the Australian curriculum: Science (Publication. Retrieved January 8, 2010, from Australian curriculum, assessment and reporting association: http://www.acara.edu.au/verve/_resources/Australian_Curriculum_-_Science.pdf.
National Research Council of America. (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.
National Science Board. (2007). National action plan for assessing the critical needs of the US science, technology, engineering and mathematics education system. Published online at http://www.nsf.gov/nsb/documents/2007/stem_action.pdf: National science foundation.
National Science Teachers Association. (NSTA) (2007). NSTA position statement. The Integral Role of Laboratory Investigations in Science Instruction [Electronic Version]. Retrieved October 23, 2009 from http://www.nsta.org/about/positions/laboratory.aspx.
Osborne, J., & Collins, S. (2003). What "Ideas-about-Science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*(7), 692–720.
Porlán, R., & del Pozo, R. M. (2004). The conceptions of in-service and prospective primary school teachers about the teaching and learning of science. *Journal of Science Teacher Education, 15*(1), 39–62.
Prosser, M., Trigwell, K., & Taylor, P. (1994). A phenomenographic study of academics, conceptions of science learning and teaching. *Learning and Instruction, 4*, 217–231.
Sandoval, A. W. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*, 634–656.
Schwab, J. J. (1960). Inquiry, the science teacher, and the educator. *The School Review*, *68*(2), 176–195.
Seroussi, M. J. (2005). *Science teachers' perceptions and implementation of classroom inquiry*. Unpublished doctoral dissertation, The University of Connecticut, Connecticut.
Wheeler, G. F. (2000). The three faces of inquiry. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 14–19). Washington, DC: American Association for the Advancement of Science.