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Action Research: First-Year Primary School Science Teachers' Conceptions on and Enactment of Science Inquiry in Singapore

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Abstract

This action research project examines first year science teachers' conceptions of scientific inquiry and their challenges in implementing inquiry-based lessons. Classroom observations and interviews represent two first-year primary school science teachers' conceptions of science as inquiry. Because the current educational landscape emphasizes inquiry-based learning as a foundation of science education, teacher-training in Singapore focuses on augmenting the quality of inquiry-based science lessons. Through a mandatory reduced workload, first-year primary school science teachers can focus on transitioning from being student teachers to full-time teachers. A video of each teacher's lesson was analysed using the EQUIP (Electronic Quality of Inquiry Protocol) instrument. Data analysis of the interviews involved a process of a priori coding based on the essential features of inquiry as well as grounded theory to expose the challenges the teachers faced in their enactment of inquiry-based instruction. Findings suggest that the two first-year teachers formed conceptions of inquiry through their teacher training programs. The teachers revealed three key considerations that affected their practice of inquiry: (1) assessment demands, (2) lack of resources and (3) lack of time to plan and to teach inquiry lessons. Findings in this action research project provide salient implications for other Asian countries which need to improve in-service teacher professional development programs in order to successfully enactment inquiry-based instruction.

Keywords: Inquiry-based instruction, EQUIP (Electronic Quality of Inquiry Protocol), Primary science education

Background

Along with twenty-first Century Competencies, *Critical and Inventive Thinking*, the Singapore Ministry Of Education (MOE) has strongly supported student-centered or inquiry-based instruction for the sake of deepening students' science learning through three aspects: knowledge, skills and processes, and ethics and attitudes (Liew, 2013). As early as 2001, the Science Syllabus foregrounded the importance of science as inquiry, declaring "The primary science syllabus aims to provide pupils with opportunities to develop skills, habits of mind, and attitudes toward learning science" (Ministry of Education (MOE), Singapore, 2004a, p.4). In 2008, *science as inquiry* was reemphasized in the science curriculum framework. In the syllabus document, it stated that

"central to the curriculum framework is the inculcation of the spirit of scientific inquiry" (MOE, 2008a, p.1).

Beginning primary school science teachers, who entered the profession over the past eight years, in Singapore were expected to uniquely teach science based on the intended inquiry-based curriculum. Even though the Ministry put emphasis on intensive inquiry-based approaches, there is little evidence that the ministry's new policy efforts support new teachers' inquiry-based practices in their classrooms (Kim, Tan, & Talaue, 2013). This research project was conducted by the Centre for Research in Pedagogy and Practice which pointed out a predominance of teacher-centered instructional practices (Hogan & Gopinathan, 2008) in classrooms. Science teachers' content knowledge and pedagogical content knowledge in science also lagged behind that of teachers teaching mathematics.

Science as inquiry attained a renewed prominence in 2008 when inquiry was identified and adopted by Singapore MOE as a center of the science curriculum framework. Hence, the beginning science teachers in primary schools since 2008 constituted the first waves of educators who went through teacher training systems that focused on adopting the latest science syllabi (MOE, 2008a; Ministry of Education (MOE), Singapore, 2014a). Those teachers were considered and expected to become "the leader of inquiry in the science classroom" (Ministry of Education (MOE), Singapore, 2014a, p.2) because they were trained by inquiry-approaches during their teacher preparatory course. They were also expected to create a learning environment where students will nurture their sense of inquiry by negotiating different ideas.

The National Institute of Education (NIE) is the sole teacher training college in Singapore, centrally controlled by the government, and the teacher preparatory course at National Institute of Education has been constantly adapting and responding to these national shifts. The first syllabi were changed in 2008 to feature a 20% reduction in content across the board in order to enable teachers to use more engaging teaching and learning approaches (Ministry of Education (MOE), Singapore, 2014b). This demonstrates understanding and appreciation from the curriculum planners that student-centric approaches such as, inquiry-based instruction requires more time for students to learn science. The extra time freed up supports teachers' attempts to increase students' engagement of self-generative questions, claims, and evidence (Roth, Tobin, & Ritchie, 2008).

The period since 2008 also signifies greater support given to beginning teachers with the introduction of the Structured Mentoring Programme (SMP), which was supposed to be implemented across all schools (Ministry of Education (MOE), Singapore, 2006). With these changes in the teacher support programs, beginning primary teachers get better support in implementing classroom management strategies, and pedagogical supports such as lesson planning and questioning skills.

Teachers in Singapore have similar responsibilities as teachers in other OECD (Organization for Economic Cooperation and Development) countries, classified into three broad areas: (1) teaching, (2) maintaining classroom discipline, and (3) administrative tasks (OECD, 2014). However, Singapore teachers spend more time on administrative tasks and classroom management. In essence, in order to enhance beginning teachers' inquiry-based or student-centered instructional practices, they need to spend more time for improving teaching practices instead of spending time on administrative

tasks or classroom management (Boon & Kong, 2008). Since the beginning teachers from 2008 were trained with the most recent syllabi, and coupled with the 20% reduction in workload for them, they will be able to spend more time on curriculum development, which means Science classes in those schools will successfully adopt the new syllabi and enhance students' inquiry-based science learning.

Under this inquiry-based curriculum, schools become well-funded and well-equipped in order to provide various forms of inquiry-based learning environments. Since 2001, schools have been provided additional science laboratories that increased the number of labs in each school. In the first Information and Technology (IT) Masterplan, schools were given data loggers (Tan, Hedberg, Koh, & Seah, 2006). More recently, MOE made available the PERI (Primary Education Review and Implementation Committee) Science Equipment Grant, a grand sum of $36,000 (in two phases over a period of two years, from 2011 to 2012), to all government-aided primary schools, money meant for the procurement of equipment and teaching materials to enhance the learning and teaching of Science.

However, Tan et al. (2006) discovered the incompatible evidence that more than 80% of the primary science teachers still continue to implement teacher-centered learning approaches. This finding is consistent with a study of Luke, Rahim, Koh, Lau, Ismail and Hogan (2005) that grade 5 (primary 5) and grade 8 (secondary 2) science teachers were predominantly using teacher-centered inquiry-based teaching practices even though they knew student-centered instruction was necessary for students' learning. In other words, beginning primary school science teachers in Singapore who entered the profession over the past eight years were less likely to be uniquely positioned to teach science innovatively through sustained supports and intensive discussion for implementing student-centered instruction. As transitions of teachers' instructional practices require teachers' paradigm shifts, institutional and physical infrastructural supports must be provided by the Ministry.

At the same time, there is a scarcity of research which addresses how the beginning teachers form conceptions of inquiry and how their conceptions of inquiry affect enactment of inquiry (Ozel & Luft, 2013). It is necessary to carefully look at whether first-year science teachers form desired conceptions of science as inquiry that are guided by NIE. Currently, there is little study in Singapore about first-year science teachers' conceptions and enactment of inquiry. Investigating teachers' conceptions of inquiry is critical since conceptions of inquiry guide students' experiences of inquiry -based learning in the science classroom (Crawford, 2007). In other words, understanding science teachers' conceptions is predictive of how they implement inquiry-based instruction. If teachers have different conceptions of scientific inquiry, then their curriculum enactment will be different from the intended curriculum.

This study investigates how well first-year primary school science teachers are positioned to implement scientific inquiry in class, through uncovering their conceptions of scientific inquiry. Two research questions guide this study: 1) What are the first-year Primary Science teachers' conceptions of scientific inquiry? 2) What are their challenges in implementing inquiry-based lessons?

This research project focuses on two first-year science teachers' current state of understanding of scientific inquiry and enactment. At the same time, this research project looks at what types of challenges beginning teachers encounter in school. Previous

research studies have shown that first year is the most difficult and challenging year for the beginning teachers (Watzke, 2003). Such challenges may adversely influence the way of beginning teachers form conceptions of inquiry. Hence, it is important to investigate how the first-year science teachers adopt what they have learned from the teacher training program, which extensively focuses on the inquiry-based learning approach and the new syllabi.

Adopting student-centered instruction is a big paradigm shift for the beginning teachers since they must adjust themselves from students to teachers (Crawford, 2000). The beginning teachers are required to create inquiry-based learning environments based on knowledge of teaching and learning. At the same time, they need to apply inquiry learning approaches to the content knowledge. Mentor teachers are in charge of inducting beginning teachers to position their learning experiences from training to classroom teaching practices. Therefore, the results of this study could have implications on the development of a beginning teacher induction programme and long-term staff development for beginning teachers by bridging the theory-practice gap (Murray, Nuthall, & Mitchell, 2008; Ingersoll & Strong, 2011). This study also aims to expose the challenges encountered by those teachers and the relationship between their challenges and changes in their conceptions of scientific inquiry.

Literature review

This session is divided into three parts. The first two parts – the definition of scientific inquiry, and literature on teachers' conceptions of scientific inquiry – address the first research question. To address the second research question, the third part reviews the literature on the challenges of implementing inquiry-based instruction.

Part 1: Definition of scientific inquiry

The definition of science as inquiry used in the Singapore Primary Science syllabus drew heavily from the National Reasearch Council (NRC) (2000) document. The primary science syllabus (Ministry of Education (MOE), Singapore, 2014a, p.13) defined scientific inquiry as "the activities and processes which scientists and students engage in to study the natural and physical world around us. Students will be able to acquire knowledge and understanding of the natural world based on investigations, apply the skills and processes of inquiry and develop attitudes and values that are essential to the practice of science". Furthermore, 'inquiry-based learning may be characterized by the degree of responsibility students have in posing and responding to questions, designing investigations, and evaluating and communicating their learning (student-directed inquiry) compared to the degree of involvement the teacher takes (teacher-guided inquiry). In other words, inquiry is characterized as a continuum between student-directed and teacher-directed inquiry. Students will benefit from a mix of both types of inquiry so long as the five features of scientific inquiry are evident (see Appendix A).

In 1996, the NRC released the National Science Education Standards (NSES), which asserted a vision of science education that will make scientific literacy for all a reality in the twenty-first century. A fundamental understanding of inquiry revolves around students and teachers asking scientifically related questions, suggesting different kinds of scientific investigations that may involve the use of instruments like thermometers and

data loggers, developing reasonable explanations using gathered evidence, and justifying the explanations based on evidence (National Reasearch Council, 2000, p.168–169). With this notion, science inquiry teaching and learning has five essential features - engaging in scientifically orientated questions, giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanation to scientific knowledge, and communicating and justifying explanations. Those five essential features emphasize to expose students to many important aspects of science, and encourage students to develop a clearer and deeper knowledge of science concepts and processes. The result of five years of deliberation by more than 18,000 teachers, administrators, scientists, teacher educators, and others became the driving force of improvements in Singapore and other countries.

Singapore runs on a centralized system which expects to have closer alignment in teachers' inquiry-based instruction across the nation than countries where each state has their own science curricula. However, if teachers have different conceptions of scientific inquiry, then the enactment will be different and students will learn inquiry in different ways according to their teachers' understanding of scientific inquiry.

Teachers' understanding of inquiry has been displayed in various ways. *Inquiry as Scientific inquiry* (National Reasearch Council, 2000) means "the diverse ways in which scientists examine the natural world and suggest explanations based on the evidence taken from their work" (p. 23). *Inquiry as learning* (Anderson, 2007) refers to an active process of learning, something that students do, not something that is done to them. *Inquiry as teaching* (Barman, 2002; Loyens & Rikers, 2011) means teachers understand inquiry as a whole spectrum of instructional techniques that make use of inquiry practices such as generating questions, formulating hypothesis or evaluating explanations.

Since scientific inquiry can be understood in different ways, science education researchers define inquiry with different meanings (Anderson, 2007; Lott, 1983; Shymansky, Kyle, & Alport, 1983). Also, science teachers have different understanding of inquiry for example, one believes inquiry is doing hands-on activity only (Kirschner, Sweller, & Clark, 2006)or the other understood inquiry as providing minimal guidance (Barron & Darling-Hammond, 2010). When scientific inquiry means different things to different people, it comes to a point where the understanding of inquiry becomes vague and non-specific (Anderson, 2002).

The disagreement over the understanding of science as inquiry among science teachers, curriculum developers and science educators has split the community (Martin-Hauser, 2002). Without a common understanding of inquiry, generalization of what inquiry-based teaching and learning becomes difficult. If there is no shared understanding about inquiry by both the science and education faculty of a teacher preparatory institute, pre-service teachers who are going through the teacher preparatory courses will not be fully prepared to implement science as inquiry as recommended by National Reasearch Council (2000).

Part 2: Beginning teachers' conceptions of scientific inquiry

Basically, teachers' conceptions are defined as ideas, thoughts, and understandings, of which there can be a wide variety (Demir & Abell, 2010). Teachers' conceptions of inquiry may affect how they implement inquiry in the science classroom (Breslyn &

McGinnis, 2012; Crawford, 2007; Wallace & Kang, 2004). These conceptions are centered around the teachers' knowledge of inquiry and the ways to implement scientific inquiry (Lotter, Harwood, & Bonner, 2007; Windschitl, 2003). Capps and Crawford (2013) argued that elementary science teachers have a limited understanding of science as their training programmes focus more on promoting students' basic skills such as reading and writing. Even though they are mostly trained with science teaching courses, very few possesses correct teachers' understanding of scientific inquiry. Teachers who have better understanding of the National Reasearch Council guide (2000) also tend to have incomplete views of inquiry since there are limited discussions among science teachers about what scientific inquiry is and how to teach inquiry in science class (Demir, 2006).

In addition to these factors, teachers' varied conceptions of inquiry are also likely to come from differences in teachers' epistemological views of science and on effective teaching (Hashweh, 1986). Hashweh divided teachers into two groups, whether they are learning and knowledge empiricists or learning and knowledge constructivists. The empiricist teachers are likely to think that science is a body of knowledge created by an immutable scientific method while constructivist teachers supported reformed teaching processes that call for students to explore before receiving explanation.

Teachers believe good teaching must secure both students' conceptual understanding of science based on their experiencing knowledge construction processes. However, when it comes to students' high achievement scores on exams, inquiry-based learning approaches do not seem to work properly. With respect to good teaching, teachers believe conceptions of inquiry support both inquiry-based instruction and their implementations rather than students' test preparation (Windschitl, 2003; Duschl & Wright, 1989). Therefore, it is important to investigate beginning science teachers' conceptions and enactment of inquiry through teachers' lived experiences (Kim, Tan, & Talaue, 2013; Tan, Talaue, & Kim, 2014).

Kim et al. (2013) aim to uncover pre-service and in-service teachers' perceptions of inquiry-based science teaching and the challenges the latter group experienced in such a curriculum. Their sample population included 50 pre-service and 41 in-service teachers with teaching experience ranging from less than one year to more than 30 years. In a follow-up paper, Tan et al. (2014), using the same dataset from their earlier research, studied in-service teachers' perceptions of inquiry-based science teaching and the challenges they faced in an inquiry-focused curriculum. In the first study, the authors focus on comparing the similarities and differences in how pre- and in-service teachers perceived inquiry-based science teaching, whereas in the second study, the same researchers reveal in-service teachers' perceptions on inquiry as one that focused on students' abilities, knowledge acquisition, classroom environment and assessment. However, as a hypothesis in this study is that first-year primary school science teachers are better positioned to implement science as inquiry due to certain advantages such as having a mentor who provide advice to the beginning teachers based on their experiences and expertise. This article will take different notions from the research studies that were introduced above.

Before moving to the third part of my literature review on the challenges of implementing inquiry-based instruction, it is necessary to clarify that this study will not be able to draw a distinction between beliefs and conceptions, simply because the

instruments that are adopted in this study, the kind of data collected and the method of analysis do not allow me to distinguish between the two. Therefore, literature on beliefs are also reviewed in this section as both beliefs and conceptions share similar qualities. Richardson (1996) argued beliefs and conceptions are both personal constructs that guide instructional decisions and impact the representation of content. The author asserted teachers' beliefs have been found to play a significant role in the implementation of inquiry-based lessons. These beliefs can be about teaching, students, confidence to accomplish a task (self-efficacy), and subject matter (Pajares, 1992). Of these beliefs, the one about teaching and learning has an immediate influence on teachers' classroom practices (Fang, 1996). There is strong evidence that beliefs influence practice (Jones & Carter, 2007; Pajares, 1992; Richardson, 1996). Previous research studies revealed that absence of professional development programmes impact beginning teachers' beliefs about scientific inquiry (Luft, 2001; Roehrig & Luft, 2006). As Bush (1983, p.3) eloquently puts it, "The conditions under which a person carries out the first years of teaching have a strong influence on the level of effectiveness which that teacher is able to achieve and sustain over the years; on the attitudes which govern teachers' behavior over even a forty year career; and, indeed, on the decision whether or not to continue in the teaching profession." What they teach, and how well they teach it rests on the "the knowledge, skills, and commitments they bring to their teaching and the opportunities they have to continue learning in and from their practice" (Feiman-Nemser, 2001, p. 1013).

In the context of first-year teachers, the influences of effective professional development programmes to shape teachers' conceptions and beliefs cannot be understated. Teachers must have opportunities to implement inquiry-based activities based on what they learned from professional development programmes and share their inquiry instruction with other teachers and professional development programmers in order to improve their inquiry teaching practices. Therefore, teachers are able to develop their understanding of inquiry and successfully implement inquiry-based learning approaches.

Part 3: Challenges of implementing inquiry-based instruction for beginning teachers

International studies indicate that teachers, whether they are beginners or not, are challenged to implement inquiry-based instruction (Gallagher, 1989). Some common constraints that teachers face when they implement inquiry lessons are: lack of collegial supervision (Brickhouse & Bodner, 1992), lack of pedagogical skills (Adams & Krockover, 1997), lack of time (Loughran, 1994), and insufficient guides for connecting curriculum and inquiry teaching (Adam & Krockover, 1997). Teachers also need to appreciate that learning is a process that happens gradually over time (Mercer, 2008, p.35). Science teachers who implement inquiry-based lessons in their classes must be aware that students will need longer learning time as students bring to each lesson their current commonsense explanations which interfere with the one offered by the teacher (Roth, Tobin, & Ritchie, 2008).

Beginning teachers are likely to encounter further issues unique to them. Research considers a teacher with fewer than 3 years in service to be a 'beginning teacher' because of the time it takes to learn the craft of teaching (Darling-Hammond & Baratz-Snowden, 2005). Feinman-Nemser (1983) characterizes the first years of teaching as a

time of survival, adaptation and learning. The author asserts that new teachers have two jobs – they are teaching and learning at the same time.

Unique challenges in Singapore remain

Beginning teachers in Singapore are likely to encounter similar challenges in addition to some unique to their milieu. They have to understand the multiple reforms and initiatives that spewed across the Singapore education landscape since the two big agenda, *Thinking Schools, Learning Nation* (Ministry of Education (MOE), Singapore, 1997) and *Teach Less, Learn More* (Ministry of Education (MOE), Singapore 2004b), were introduced because each one of those represents an area for teachers to be accountable in. The increase of education reform initiatives has resulted in work intensification, as can be seen from the multiplication, diversification, and specialization of teachers' tasks and responsibilities, and the heightened controls on teachers' performance (Hargreaves, 1994) which usurp teachers' autonomy (Apple & Beane, 1995). The study conducted by Tan et al. (2014) reveals an atypical set of concerns faced by Singapore teachers in terms of implementing inquiry-based lessons that differs significantly from constraints faced by their international counterparts. Significant concerns that stop implementing inquiry-based instruction are: assessment conflicts between inquiry instruction and assessment demands and heavy content in the curriculum.

Another area of tension highlighted in Tan et al. (2014, p.125) was the "antagonistic relationship between the practice of science as inquiry and examination performance". This is a reflection of the performance-based culture that pervades the Singapore education system. Taken together, this emphasis on performance has been linked to teacher stress, exhaustion, and burnout (Cosgrove, 2001).

To the credit of the Ministry of Education (MOE) in Singapore, it has sought to address many of the challenges faced by teachers in implementing inquiry lessons. In addition to infrastructure and institutional support, MOE created administrative support roles in schools such as Teacher Assistants, Teacher Aides, Laboratory Technicians, ICT Executives and Co-curricular Programme Executives (Ministry of Education (MOE), Singapore 2005a) to support teachers by freeing up more time for them to devote to instructional matters (Ministry of Education (MOE), Singapore, 2005b). As mentioned before, generous financial backing has been given to schools for the purchase of equipment and teaching materials to enhance the learning and teaching of Science. The Structured Mentoring Programme or SMP (Ministry of Education (MOE), Singapore, 2006) was introduced in 2006 to provide school-level mentoring to first-year teachers. One main aim of school-level mentoring is to have mentors help beginning teachers acquire knowledge and work skills in a specific area like a teaching subject. In the period after SMP was introduced, there were several longitudinal survey studies conducted by local researchers (Choy, Chong, Wong, & Wong, 2011; Wong, Teo, & Russo, 2012) to discover the teachers' perceptions of their levels of pedagogical knowledge and skills from pre-service years to their first year of teaching. The findings revealed that beginning teachers expressed a greater sense of confidence in their pedagogical skills and knowledge by the end of their first year of teaching. Although research in mentoring in Singapore is only in its nascent stage (Ng, 2012), the positive effects of mentoring have already been acknowledged (Carter & Francis, 2001).

Methods

This study analyzes teacher interviews and lesson observation with a qualitative research design to investigate two first-year science teachers' conceptions of science as inquiry, the challenges they face in implementing inquiry-based instruction, and provide an explanation that can cope with the complexity of the reality of teaching in a Singapore school. The method section of this study focuses on whether first-year science teachers are ready to implement inquiry-based instruction when they are situated in a school that is supportive of inquiry-based instruction. The collection of detailed empirical data on the classroom practices of two first-year primary science teachers includes video recording of lessons as well as interviews with each teacher. These data are complemented by artifacts such as lesson plans and the teacher's personal timetable.

Data collection

Research participants

The two beginning teachers, 'Ken' and 'Yvonne' (pseudonyms), met the research requirement of first year science teachers. All the participants had completed a post-graduate diploma in education (PGDE) from the NIE. Both teachers had no prior working experience (see Table 1).

Research site

The two teacher participants, Ken and Yvonne, were from Reform Primary School (a pseudonym). Reform Primary school was a 'neighborhood' school in the north with a population of around 1000 students and 60 teachers, of which 14 were science teachers. At the time of the study, more than 50% of the teachers in the school had five or fewer years in teaching experience. Out of the fourteen teachers teaching science this year, six had three or fewer years of teaching experience.

The school was chosen based on its efforts to implement inquiry-based instruction. Reform Primary School has implemented a science curriculum redesigned around inquiry-based learning approaches since 2009. Science teachers in this school have been monitored for successful adoption of the school-based curriculum, which included problem-based learning and project-based learning at primary levels 3, 4 and 5. The combination of these two factors – a young teacher population and the presence of a seemingly effective inquiry-based curriculum – led to make the decision to explore the experiences of the beginning teachers in this school.

It was necessary to communicate clearly with the participants in order to collect valid data. Through interactive communication between researchers and participants before conducting this study, the participants had a clear understanding of the purpose and

Table 1 The profiles of the two teachers

Details	Ken	Yvonne
Age	28	25
Gender	Male	Female
Years of teaching experience	1	1
Educational Background	Degree holder	Degree holder
Science classes involved in study	P3 with 40 pupils	P4 with 40 pupils

procedures of this study. Two participant teachers agreed with conducting classroom observations and interviews because those data vividly display the beginning teachers' experiences and challenges as first year Science teachers who tried to implement inquiry-based instructions in their classroom.

Data analysis

To investigate the first-year science teachers' lived stories in the classroom, data analysis focused on teachers' perceptions and beliefs that were underneath their teaching practices. At the same time, this study focused on answers to research questions: All teacher classroom observations and interviews were transcribed by the project investigator. And EQUIP (Electronic Quality of Inquiry Protocol) was utilized during two coding cycles: in the first cycle, teachers' classroom discourses such as questions and dialogues with students and interviews were coded separately, and in the second cycle, a cross-coding procedure was conducted to produce integrated themes based on codes from the first cycle.

Coding video taped lessons

Two inquiry-based science lessons (4 half-hour school periods) were recorded over two school days. All teacher instruction was transcribed and coded to identify the features of inquiry. EQUIP was chosen to identify features of teachers' discussions and inquiry-based instruction in this study. EQUIP is a validated and reliable instrument developed to assess the quality and quantity of inquiry in K-12 math and science classrooms. The instrument used the NRC's definition of inquiry (National Reasearch Council, 2000) as a point of reference. Since the definition of inquiry has been appropriated into the Singapore Primary Science Syllabus, a guiding document for science teachers to abide by, EQUIP can be used to guide teachers' discussions and analyses of inquiry-based instruction in this study.

In preparation for coding using EQUIP

The coding process was repeated several times to increase validity (Marshall, Horton, Smart & Llewellyn, 2008; Marshall, Horton & White, 2009; Marshall, Smart & Horton, 2010; Smart & Marshall, 2013). Appendix B shows the coding schemes used through EQUIP.

Transcripts from the two participant teachers were segmented into five-minute intervals. At each five-minute interval, 19 different indicators that support inquiry-based teaching and learning were used to assess the way the time was utilized.

These indicators were considered across five factors, namely: time usage, instruction, discourse, assessment, and curriculum. The indicators for each factor were individually assessed before a holistic score was given to each factor based on the level of inquiry. This score may not be a mean value of the independent indicator scores, but it reflects the essence of the lesson. There were four inquiry levels, with a score of 1 given to Pre-inquiry, 2 to Developing Inquiry, 3 to Proficient Inquiry, and 4 to Exemplary Inquiry. Scores of 3 and 4 were considered to be very inquiry-based. A score of 0 was given if the lesson revolved around non-instructional activities like the collection of homework or discipline.

Coding interview responses

Both teachers' interviews were conducted a week after each lesson observation. All teacher interviews were audiotaped and transcribed, and then analyzed through EQUIP.

Five following ideas related to the research questions came up with while interview was conducted: (a) teacher's conceptions of scientific inquiry, (b) the roles of students in an inquiry classroom, (c) the roles of teachers in an inquiry classroom, (d) the importance of teacher's personal experiences in shaping his or her conceptions of scientific inquiry, and (e) challenges faced by a first-year science teacher.

In order to create codes based on teachers' responses to the first three questions, a priori coding scheme was used by focusing on the five essential features of inquiry spelled out by National Reasearch Council (2000). All statements mentioning any considerations of any of these features were included in the data analyses. The rationale for selecting those five features of interview questions were: first, these five features were adopted in the primary science curriculum framework in Singapore, and second, these five features were also used as a framework for data analysis in two previous studies (Kang, Orgill, & Crippen, 2008; Tan et al., 2014).

In terms of the teachers' responses to the fourth and fifth questions (d and e), it was considered that each teacher may have unique experiences based on school situations they were teaching in now. The one-to-one semi-structured interview (Denscombe, 2010, p.175) was chosen to explore issues the beginner teachers faced in implementing inquiry-based lessons in order to gain insights into the teachers' feelings, opinions, and experiences. The theoretical basis for the coding process followed grounded theory (Glaser & Strauss, 1967).

The initial questions used to first find the challenges teachers face in school were adapted from Morrison's (2013) paper, *Exploring Exemplary Elementary Teachers' conceptions and implementation of inquiry science*. The categories developed from the one-to-one interviews were: (a) teachers' conceptions, ideas, or beliefs about inquiry, (b) factors that had led to teachers' conceptions of inquiry; (c) barriers to teaching inquiry science, and (d) suggestions to help beginning teachers teach inquiry science.

Coding responses to lesson scenario

In addition to the interview questions, a lesson scenario was posed to each teacher in which the teacher was asked to share his or her thoughts of how to plan an ideal inquiry-based lesson on the topic of having students classify substances based on their observable properties. A priori coding scheme was adapted from the five features of inquiry.

In coding the interviews, two rounds of coding were conducted. The second round of coding was carried out two weeks after the first attempt, and a comparison between both sets of coding was done to surface and resolve discrepancies in interpretations. This procedure was done to simulate having multiple coders doing the coding. Based on these coding results, the emergent themes and concerns of inquiry teaching were created.

Results

The results highlight two sections that correspond to the two research questions. The findings regarding the first year science teachers' conceptions of inquiry are presented

first, followed by the findings of the challenges faced by these teachers in implementing science as inquiry.

RQ1: Teachers' conceptions of inquiry: Teachers' definition of inquiry

Both teachers were asked to define and explain their understanding of an inquiry-based lesson in the interview. Ken believed that there are two kinds of inquiry, the ideal inquiry and the structured inquiry:

> "Inquiry can be very open like the kids asking a question and wanting to find out about something, but then because in school we are constrained by the syllabus, we have to complete whatever that has to be taught, so the kids will not have this luxury of asking their own questions, you know, and coming out with a research plan, you know, and go and investigate and stuff like that so right now what I have been doing has been the very structured kind, this is something we want to find out, lets find out about this and lets explain about what happened during the investigation."

He posited that ideal inquiry is a process of learning that begins with the students posing questions and exploring possible solutions before the teacher offers the explanation. However, Ken was quick to reiterate his position that ideal inquiry cannot happen in reality, due to the constraint of time, assessment concerns, and the need to complete the syllabus on time:

> "But in school, the reality is different. How do we find so much time to do all of these? And we have been like pushing this (inquiry-based instruction) to like do this after the exams. Like last year, for PBL (problem based learning), we did it after the exams. No time already; we have to prepare them for exams."

Ken found that *the structured inquiry* is the only kind of inquiry that is possible, as he felt *constrained by the syllabus*.

In the interview, Yvonne mentioned conceptions of science as inquiry that reflect a different perspective from Ken:

> "Inquiry-based lesson is one where the students are the owners of their own learning. Teachers provide the resources and scaffolds. And then the pupils are free to explore and come up with their own conclusions. There is no right or wrong in the process of inquiry."

She defined inquiry in terms of the roles and responsibility of the students and teachers. In an inquiry-based lesson, the learners take on greater responsibilities for their learning and they have to be the inquirers, the teachers take a more backseat role of scaffolding the learning environment and presumably learning task, and through these efforts, teachers empower students to inquire.

Teachers' conceptions of inquiry: Teachers' experiences

The teachers' personal experiences prior to teaching affected them to different extents. In Ken's case, his pre-service training at the NIE helped reinforce his belief that science education should be inquiry-based. However, his first year of teaching has challenged that belief. Yvonne's experience was as a student who did not receive inquiry-based

instruction. Learning science in the rote-learning manner was a chore for her, and even though that approach helped her to get good grades, she did not wish for her students to see science as boring.

RQ2: Challenges in implementing inquiry-based instructions

Throughout the interview, both teachers shared their thoughts on the challenges they faced as first year science teachers attempting to practice inquiry science. Although there were similarities in some of their challenges, such as the lack of curriculum time and inquiry being dependent on pupils' readiness, these teachers from the same school differed in their emphasis. Ken's primary obstacle to practicing inquiry is that of summative assessment:

> "Why do we have learning sheets (handouts) after learning sheets? I think it is to get them used to be asked the type of question during exams. So if there is less emphasis on exams, there will be fewer learning sheets, and maybe we just concentrate on the activities in the workbook."

His frustrations at the system came through loudly, and for a first year teacher, Ken was already jaded. He experienced a lot of tension between his belief about teaching science and the way he felt he was compelled to teach science, due to the academic focus in school,

> "I have been thinking about this. Am I teaching science inquiry or am I teaching them how to answer questions for exams? And I find myself doing the answering-questions-for-exam more than getting them to be really curious about coming up with their own questions to ask about the world and investigate it on their own."

His sense of helplessness was also evident because he did not see himself, or even the school leader, as the change agent. The only way to resolve this tension was to remove or change the system of assessment,

> "I think this is a nationwide thing… so it is very hard to change this at the school level, unless there is a bigger change up there or something like that."

Yvonne focused on a different set of challenges. The tension Ken faced with examination was not even mentioned at all by Yvonne. Her two main obstacles as a trained teacher with a full teaching load would be the lack of time to plan inquiry lessons as well as the lack of resources.

> "Oh… this year, I was actually very sad that the learning journey to the science center is not…we don't have the budget or the resources to bring them there… they were actually very, very disappointed because some of them have siblings in the previous years and they know there were learning journeys to the Science Centre, so they kept asking me when they would be going to the science center this year. And when I said we were not going, they were very, very disappointed."

By resources, she referred to funding for learning journeys and manpower. Such challenges, if unresolved, would rob her students' of rich learning experiences.

What helped them and what could have helped them

Although both teachers mentioned that the Teachers' Learning Community (TLC) every Monday was a platform that provided them with support, Yvonne appeared to have found more help than Ken, from such formal as well as other informal platforms in the school. Besides having learnt a lot from the TLC sessions actually in terms of questioning techniques in science, something that she felt was useful because she got opportunities to discuss questioning skills with experienced teachers in the TLC. Yvonne also tapped into the expertise of Senior Teachers and other experienced teachers to clarify her doubts. She formed informal communities with colleagues from the same teaching level to exchange teaching ideas. Although her focus was to deliver a more effective lesson rather than a more inquiry-based lesson, such support nonetheless helped her to cope with the challenges of being a first-year teacher.

As a follow up to the challenges she faced, Yvonne believed that if she as a first year teacher was given fewer teaching periods, she would have more time to prepare inquiry-based lessons. Also she felt that it would be helpful to have Senior Teachers demonstrate the enactment of inquiry-based curriculum to beginning teachers. As Senior Teachers were selected teachers based on their teaching experiences, content and pedagogical expertise, they could provide empirical advice to beginning teachers.

Assessing the level of inquiry using EQUIP

During the interview, teachers may share their beliefs about how inquiry science should be enacted, but these may not be congruent with their actual classroom practices. Therefore, data triangulation (Patton, 1990) was used to validate my interpretation of the data about the teachers' conceptions of inquiry, which was why apart from the interviews and the teachers' way of planning an ideal inquiry lesson, the EQUIP instrument was also used to assess the teachers' Level of Inquiry as observed in action.

Summative overview after using EQUIP

The teachers' practices were deemed to be congruent with the beliefs on inquiry which they expressed during the interview. After considering all the five factors, both teachers were observed to have performed between Pre-Inquiry (Level 1) and Developing Inquiry (Level 2), and a holistic score of Developing Inquiry (Level 2) was assigned to both teachers (Table 2). For a more detailed presentation of the scores across all 19 indicators (Appendix C). However, I shall highlight some findings below.

The beginning teachers often got students to observe, an inquiry process skill. Ken repeatedly asked his students if they could see an increase in the number of paper clips that were supposed to be attracted to their magnetized steel scissors, while Yvonne

Table 2 Holistic score of teachers

Factors supporting Inquiry	Ken	Yvonne
Inquiry Instructional Factors	2	2
Discourse Factors	1	2
Assessment Factors	1	1
Curriculum Factors	2	2
Mean Level of Inquiry Score	1.55	1.85
Holistic Level of Inquiry Score	2	2

asked her pupils to observe phenomena. Although both teachers did get some of their students to explain their answers or what they saw, they were rarely asked to justify their explanations.

When examining the teaching practices of Ken and Yvonne, they predominantly implemented a teacher-directed pedagogy. The use of lecture, didactic styles of teacher questioning, and teacher follow-up (Initiate-Response-Follow up, IRF) was evident. The flow of the lesson followed by a monological communication: a teacher gives directions and students follow their teacher's guide. In Ken's classroom, often, learning was focused on rote learning and memorisation, such as the spelling of key words (e.g. temporary) and the emphasis on one correct answer (e.g. giving students a 'template' to answer a relationship question). In Yvonne's case, although she used questioning extensively in the lesson, the level of questioning was focused on the test preparation, and the conversations were still mainly the IRF type.

Discussion

With the two research questions that feature how the beginning primary science teachers' develop their perceptions of scientific inquiry, this study discovers there is an obvious tension between their understanding of ideal inquiry and implementation challenges. Comparing their conceptions of inquiry, which according to National Reasearch Council's definition (1996), described the three domains of inquiry as: abilities of students to conduct inquiry, students' understanding of inquiry so they know how science and scientists work, and teaching standards and strategies, it is gratifying to know that these first-year science teachers already expressed conceptions of inquiry that are compatible with the first and third domains. The lived-experiences of both teachers in the Singapore education system throughout their years as students would have imprinted upon them one mode of instruction – a predominantly transmissive, didactic model (Roehrig & Luft, 2004). That much is stated by teacher Yvonne during the interview.

> "NIE is still pretty fresh in my mind…There was a big portion on inquiry as in you know the basis of science lessons or curriculum."

Hence, it is reasonable to state that the teacher preparatory course at NIE strongly influenced their beliefs of inquiry and what constitutes *good teaching*, and to some extent regarding the necessity of the use in inquiry in science lessons. At the same time, it is crucial to highlight the gaps in their conceptions. While the teachers showed an appreciation that scientifically oriented questions are key to scientific inquiry in the classroom (National Reasearch Council, 2000, pp. 24–27), they over-emphasized the skills such as observing, rather than on the development of their students' ability to think as scientists and to think scientifically. The teachers gave little priority to evaluating evidence, formulating reasonable explanations from evidence and justifying their explanations, all of which are essential features of classroom inquiry. The beginning teachers have to gain an understanding of inquiry as apart from the belief that inquiry is made up of single process skills (Lederman, N.G. & Lederman, J.S., 2004).

Researchers have found that teachers' conceptions (Crawford, 2007) and beliefs (Fang, 1996; Richardson, 1996) strongly affect the way that they implement inquiry in the classroom. The experiences of the two teachers through their teacher preparatory course at NIE and their personal experiences as science students shaped their ideas about science learning and teaching, yet their experiences as fully trained teachers, in a school that advocates the use of inquiry in its Science curriculum no less, imply that curricular demands and constraints threaten to override their beliefs that science as inquiry is the way students should learn science. The participants' challenges are not unique. Tan et al. (2014) report that assessment, curriculum content, and preparation made up 35.8% of all the perceived difficulties in inquiry practices. However, what is surprising is that the first year teachers in this study also flagged these concerns and more. Instead of being given fewer teaching periods, they were not offloaded. Instead of being supported in terms of resources, especially in the wake of the PERI Equipment Grant and other funding, teachers were faced with the unlikely problem of lack of resources to even send students for outdoor learning experiences. Instead of allowing students to explore and investigate, the ever-present academic targets loomed. It was apparent that these teachers could not escape the pervasive performativity culture of the education system (Ball, 1998).

The supporters of a performativity education system would argue its necessity to close the implementation gap (Hargreaves & Fullan, 1992) because an improvement in academic scores of students, especially those from poorer backgrounds, is a big achievement for government policies intended to benefit both the society as well as the individual. The rise of the performativity discourse is on the back of the adoption of market structure for schools to enhance the effectiveness and efficiency of outputs of learning and to provide more choices for consumers of education (Ball, 1998).

However, a performativity discourse distorts teachers' work because it pressurizes teachers to perform and deliver results, instead of exploiting children's natural curiosity and interest in learning (Central Advisory Council for Education, 1967). Teacher-guided inquiry will be appropriate to the learning situations of two teachers, where students not only explore their own interests by engaging in inquiry-based activities, but also learn scientific concepts in the curriculum. Even though a high degree of professional accountability to their students' academic performance limit their autonomy (Warwick, 2007), teachers provide inquiry learning opportunities to students by adjusting their pedagogical practices.

A source of comfort for Yvonne was the presence of a supportive professional community. It was not only provided her with professional developmental opportunities through the TLC platform, the collegial culture encouraged her to approach the experienced teachers for help. A review done by Ingersoll and Strong (2011) of over 15 empirical studies spanning almost 30 years concluded that most of these studies supported the claim that support and assistance for beginning teachers have a positive impact on teacher retention, instructional practices, and student achievements. Yet, why did Ken not seek out similar support from the school? Could their gender differences have a role in how they exhibit their responses to classroom challenges (Kardia & Wright, 2004)? This provides a possible area for future research.

Implications on changing teachers' conceptions

The first implication is that the intentions at the institutional level to support beginning teachers through a reduction in teaching load should be reflected in the school. The argument of prioritizing, a school's needs ahead of beginning teachers, should be reconsidered. Thrusting beginning teachers into the thick of teaching without affording them sufficient adjustment time and support could lead to an increase in the attrition rate (Ingersoll & Smith, 2003).

The second came from the collegial support Yvonne experienced, which shaped the way she perceived the challenges of implementing Science as inquiry differently from Ken. The school could provide opportunities for beginning teachers to interact with Senior Teachers. The platform provided by the weekly TLC sessions is one such example where Senior Teachers modeled inquiry practices. More could be done. If the school can develop an Induction Programme for novice teachers to learn directly from experienced practitioners in a 'community of practice' (Lave & Wenger, 1991), this will allow the beginner teachers to access aspects of this professional knowledge and gradually develop their professional identity.

Conclusions

This study investigates if first year science teachers are well positioned to implement scientific inquiry in class through uncovering their conceptions of scientific inquiry (National Reasearch Council, 2000). It also aims to bring to light the challenges encountered by these teachers and how these challenges could have changed their conceptions of scientific inquiry. The findings suggest that the first year science teachers in this study shared common conceptions on scientific inquiry with some variations. These indicate some successes of NIE's teacher preparatory course in developing a consistent conception of science as inquiry. Having experienced senior teachers as mentors also provided first-year teachers with much needed pedagogical support. However, they still experienced challenges in their practice of inquiry. The complexity of these challenges and experiences that affect first-year teachers' conceptions of inquiry should be acknowledged and foregrounded. Finally, the assumptions of existing policies and programmes designed to help teachers to bridge the theory-practice gap are enacted as intended have to be reexamined.

Limitations

There are possible biases in interpreting participant teachers' interviews because they are former colleagues of the primary investigator (PI). In addition, as the PI is the Science HOD of the school, participants may withhold or overcompensate when they share their thoughts related to both Science TLC and Science department programmes. Also, there is a possibility that the EQUIP coding results can be biased by the PI, although a check against the online training exemplars for EQUIP showed a high degree of agreement between codes and the exemplars. The qualitative coding process went through several rounds to enhance validity, however, the data analysis results can be subjective in that the PI reflected personal beliefs and theoretical views to data interpretation. Finally, the participants had to remember incidents from their past, and memories are subjected to incorrect representations or lapses.

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Availability of data and materials
The study was reviewed and approved for ethics clearance by the internal committee as authorized by NTU-IRB. All teacher participants provided informed assent prior to data collection.

Authors' contributions
The first author JLSC conducted this research project and drafted the manuscript. The corresponding author YB drafted the final manuscript. Both authors read and approved the final manuscript.

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