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‘Am I Like a Scientist?’: Primary children’s images of doing science in school

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A considerable body of evidence highlights how inquiry-based science can enhance students’ epistemic and conceptual understanding of scientific concepts, principles, and theories. However, little is known about how students view themselves as learners of science. In this paper, we explore primary children’s images of doing science in school and how they compare themselves with ‘real’ scientists. Data were collected through the use of a questionnaire, drawing activity, and interviews from 161 Grade 4 (ages 9–10) students in Singapore. Results indicate that ‘doing science as conducting hands-on investigations’, ‘doing science as learning from the teacher’, ‘doing science as completing the workbook’, and ‘doing science as a social process’ are the images of learning science in school that most of the students held. In addition, students reported that they need to be well behaved first and foremost, while scientists are more likely to work alone and do things that are dangerous. Moreover, students often viewed themselves as ‘acting like a scientist’ in class, especially when they were doing experiments. Nevertheless, some students reported that they were unlike a scientist because they believed that scientists work alone with dangerous experiments and do not need to listen to the teacher and complete the workbook. These research findings further confirm the earlier argument that young children can make distinctions between school science and ‘real’ science. This study suggests that the teaching of science *as* inquiry and *by* inquiry will shape how students view their classroom experiences and their attitudes towards science.

Keywords: *Inquiry science; Primary school science; Student drawing; Science student roles; Scientist roles*

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Introduction

The contemporary science education reforms (Duschl, Schweingruber, & Shouse, 2007; National Research Council, 2000, 2012) focus on raising scientifically literate citizens, who should not only understand how science works and what it can do for them, but can also play an active role in making decisions and engaging in debates concerning scientific issues (Dillon, 2009; Roth & Calabrese Barton, 2004). In order to achieve this goal, science education should involve students in authentic experiences of inquiry-based learning to develop an epistemic and conceptual understanding of real-world phenomenon, skills for conducting scientific investigations, and abilities for problem solving (Anderson, 2002; Duschl, 2008). Teaching science as inquiry was initiated by the US National Research Council (1996) more than 15 years ago and has already been internationally recognised by science education communities around the world (Abd-El-Khalick et al., 2004). Teaching science as inquiry has been described as facilitating students to 'develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world' (National Research Council, 1996, p. 23). In this regard, inquiry[1] can be viewed as 'doing what scientists do'. But, how do the students view school science and real-world science? Do they view themselves as 'little scientists' when they are doing science in school? In this paper, we examine fourth graders' conceptions of doing science in school through their drawings as well as their verbal descriptions of what school science is like.

Theoretical Framework

This study is informed by the core constructs of science as inquiry and students' perceptions of school science. In the following sections, we review the literature and discuss how the ideas presented in the literature shape this study.

Science as Inquiry

Scientific inquiry is agreed upon as the methods and activities that lead to the development of scientific knowledge (Schwartz, Lederman, & Crawford, 2004). More specifically, the National Science Education Standards defined scientific inquiry as

> a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse and interpret data; proposing answers, explanations, and predictions; and communicating results. (National Research Council, 1996, p. 23)

In this respect, within the context of a classroom, scientific inquiry represents a set of abilities and understandings that include asking scientifically oriented questions, giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific knowledge, and communicating and justifying explanations (National Research Council, 2000). With this set of abilities and understandings, students can make sense of the values and assumptions of the knowledge and the processes by which the knowledge is created rather than simply constructing an image of science as isolated facts (Schwartz et al., 2004). In other words, learning science as inquiry exposes students to a type of learning that parallels the work of scientists, helps students develop deeper understanding of science, and thus can lead to the development of critical thinking skills.

The understandings of scientific inquiry reflect the philosophical nature of nature of science (NOS), which highlights the dynamic perspectives of knowledge and enterprises of science itself, that is, 'science as a human endeavour, directed by theory and culture, reliant on empirical observation, and subject to change' (Schwartz et al., 2004, p. 612). Inquiry-based instruction is argued to offer a context for learning NOS, but the effectiveness of students' understanding about NOS is shaped by different instructional contexts (Khishfe & Lederman, 2007). Research has shown that students would not automatically learn about NOS merely through the engagement in inquiry-based activities (Moss, Abrams, & Robb, 2001). Alternatively, explicit instruction of NOS as embedded within the context of classroom-based inquires has been found to substantially improve students' understanding of NOS (Akerson & Donnelly, 2009; Khishfe & Abd-El-Khalick, 2002). Therefore, to teach NOS within the context of inquiry, teachers should change their role from a dispenser of knowledge to a coach and facilitator of student-directed scientific inquiry and give explicit attention to NOS issues (Anderson, 2002; Schwartz et al., 2004).

Authenticity has been considered as a significant construct for teaching and learning science as inquiry (Chinn & Malhotra, 2002; Crawford, 2007, 2012). According to Brown, Collins, and Duguid (1989), 'authentic activity . . . is important for learners, because it is the only way they gain access to the standpoint that enables practitioners to act meaningfully and purposefully' (p. 36). For many, however, authenticity in the science classroom is a synonym for the kinds of work scientists do and is relevant to students (Braund & Reiss, 2006). Research has shown that simply having students do what scientists do without any modification of the science content and instructional methods would not help students realise that science is authentic (Rahm, Miller, Hartley, & Moore, 2003). As Osborne and Patterson (2012) point out, the goals of doing science and learning about science are different. When doing science, scientists aim to create new knowledge. However, when learning about science, students aim to understand pre-existing knowledge. Therefore, 'the issue is not whether it is an authentic scientific activity *but whether it is an authentic educational activity*' (Osborne & Patterson, 2012, p. 816; emphasis in original). Consequently, an emergent notion of authenticity that includes dynamic interactions between the teacher and the learner through collaborations and ongoing negotiations (Crawford, 2012; Rahm et al., 2003) becomes critical for promoting and enhancing inquiry-based science education.

In order to promote science as inquiry, there is a call for teaching of science *as* inquiry or *by* inquiry (Crawford, 2007). However, the usage and understanding of these two phrases are diffuse and have been used interchangeably. Kirschner, Sweller, and Clark (2006) distinguish *teaching of a discipline as inquiry* (i.e. a curricular emphasis on the research processes within a science) as *learning a discipline* and *teaching of a discipline by inquiry* (i.e. using the research process of the discipline as a pedagogy or for learning) as *practicing a discipline*. Similarly, according to Tamir (1983), the teaching of science as inquiry refers to 'the substantive focus of the classroom, *what* is taught, and hopefully, learned' and the teaching of science by inquiry defines '*how* teaching and learning are executed, the nature of classroom transactions, and the inquiry skills that will be practiced' (pp. 658–659; emphasis in original). That is, through the teaching of science by inquiry students develop attitudes, inquiry skills, habits of mind, while through the teaching of science as inquiry students obtain a realistic image of science and its nature (Chiappetta, 1997). In this study, we investigated how students view scientists and scientists' work through the lens of science *as* inquiry; we also investigated how students interpret their science classroom practices through the lens of science *by* inquiry.

Students' Views on Scientists and School Science

As students learn science, 'they also learn a lot about who they are (and can be) and what science is (and can be)' (Calabrese Barton, 1998, p. 443). Thus, to understand learning in science, it is important to find out 'whether students see themselves as the kind of people who would want to understand the world scientifically and thus participate in the kinds of activities that are likely to lead to the appropriation of scientific meanings' (Brickhouse, Lowery, & Schultz, 2000, p. 443). In this respect, in an inquiry-based science classroom, students are expected to act in ways related to the practice of scientists. Thus, it is important to understand how students view the work of real-life scientists and how they position themselves when learning science in class.

Previous research on students' perceptions of scientists using the Draw-a-Scientist Test and its supplemental interviews has revealed that the most typical image of scientists portrayed by students is that of an elderly or middle-aged man who works individually in a traditional indoor laboratory settings and wears a lab coat and glasses while conducting dangerous experiments (Chambers, 1983; Finson, 2002; Koren & Bar, 2009; Newton & Newton, 1998; Song & Kim, 1999). However, these studies failed to find out children's epistemological understanding of science and especially their identities as scientists. In order to explore young children's conceptions of themselves as scientists and how they represented certain kinds of identities involving certain kinds of ideological commitments to the NOS, Tucker-Raymond, Varelas, Pappas, Korzh, and Wentland (2007) asked 36 primary school students from three different lower grades to draw and discuss two pictures of times when they were scientists. The results of data analyses showed that young children can and do see themselves as scientists engaged in culturally authentic scientific practices with a range of materials, for a variety of purposes, and with particular kinds of epistemological commitments. Based on these findings, the authors proposed that the methodological consideration of using 'dialectical unity of drawing and speech worked as a multimodal, mediational tool to express children's ideological commitments to scientists and the activities scientists engage in' (Tucker-Raymond et al., 2007, p. 589).

Furthermore, Shanahan and Nieswandt (2011) have explored 10th graders' perceptions of school science. Based on the analysis of qualitative interview data and quantitative survey data, themes such as 'intelligence', 'being and acting scientific', 'being skilled in science', and 'behaving well in class' were identified as the most outstanding roles of science students. Similar findings were reported in Archer et al.'s (2010) study based on a series of focus group interviews with 42 sixth-grade students from four primary schools in the London area. The students acknowledged that science is hard and requires that they use their brains a lot which is similar to the notion of intellectual rigour as reported by Shanahan and Nieswandt's (2011) students. Archer et al. (2010) also found that young people can make a clear distinction between doing school science and the science of scientists, that is, students of science re-discover the scientific knowledge that has already been known, whereas scientists explore authentic scientific issues and develop novel knowledge. However, some discrepancies were identified when students talked about doing science and becoming scientists. For instance, some students possessed a negative view on becoming scientists and viewed scientists as boffins. It has been argued that the science boffin is represented by the stereotypical images of the scientist and 'boffin identities reside dangerously close to "geek" (or nerd) identities—a stigmatised social/learner identity that many children seek to avoid' (Archer et al., 2010, p. 634).

To study how African-American children frame themselves relative to science and scientists, Varelas, Kane, and Wylie (2011) conducted a case study with 25 students in early primary grades by using conversations in which they discussed their science journals. It was found that students' conceptions of 'doing science' was fused with their conceptions of 'doing school'. That is, the academic disciplines, such as listen to the teacher, be quiet in the classroom, and so forth, were reported by the students as their ideology becoming relative to the practice of science which is 'antithetical in some ways to active, inquisitive, questioning, flexible view of science and science learning' (p. 825). The authors argued that the ways students saw science and themselves were influenced by '[h]ow they were socialized in the classroom, and how they perceived their teacher and peers seeing them' (Varelas et al., 2011, p. 845). In this regard, students' classroom experiences have a great potential to shape students views and perceptions of science and themselves as learners in the community of a science classroom.

Research Context and Purpose of the Study

According to the Trends in International Mathematics and Science Studies 2007 results, Singapore had high percentages of students reaching the advanced benchmark—36% at fourth grade, which was nearly twice of the percentage of students in the country ranked second (Martin, Mullis, & Foy, 2008). This means that more than one-third of Singaporean Grade 4 students can apply knowledge and understanding of scientific processes and relationships in beginning scientific inquiry. To maintain the achievement of science education and further enhance students' twenty-first century skills, the Singapore government introduced a new primary science syllabus, which was deigned to be more inquiry centric, stating that 'central to the curriculum framework is the inculcation of the spirit of scientific inquiry' (Ministry of Education, 2008, p. 1) and emphasises nurturing students as inquirers. This also requires teachers to be the leaders of inquiry by creating a learning environment that encourages and challenges students to develop their sense of inquiry.

However, recent studies have revealed that some primary school teachers in Singapore had difficulties and dilemmas when teaching inquiry science. For example, Talaue and Tan (2011) investigated the factors that influence teachers' intention to teach science as inquiry through analysis of questionnaires completed by 194 teachers from 42 primary schools in Singapore. The authors found that the majority of the teachers held a moderate to strong positive attitude towards implementing science inquiry teaching and believed that such a pedagogical approach could deepen learning of science concepts, enhance self-regulation, and develop higher order thinking skills; however, factors, such as the need to help students pass examinations, the lack of facilitating skills, the need to complete the syllabus, and low ability of some students, would limit the teachers' ability to enact inquiry-based teaching. Similar findings were reported in Tan and Wong's (2012) study, which noted that the overemphasis on the teaching of science content would result in learning experiences in which students mechanically memorise a reductionist and simplistic model of science, and ignore developing a deeper conceptual and epistemic understanding of science. In another study on the sequences of inquiry in primary science classrooms, Poon, Lee, Tan, and Lim (2012) found that the pedagogical component of consolidating students' knowledge was included as the summarising phase of teaching, something that was not evident in the existing pedagogical frameworks of inquiry. In fact, the structure of the Singapore primary science syllabus included a number of concepts within a topic. The consolidation phase enables students to synthesise the various concepts they have learned over a series of lessons on the same topic and thus to develop the ability to make connections across concepts demanded by the high-stake national examinations. The inclusion of the consolidation phase implied that teachers' pedagogical decisions were impacted by 'their local context of meeting important curricular and assessment demands in their adoption of inquiry practices' (Poon et al., 2012, p. 323).

Given the fact that teachers experience dilemmas and tensions in their practice of science as inquiry in classroom situations, the voice of students will help us understand the challenges and potential solutions of the intended curriculum in Singapore primary science classrooms. This study was set out to investigate how students view themselves as scientists and science students and what factors affect their learning science as inquiry. The research questions guiding our study are as follows:

(1) How do primary school students view their experiences in a science classroom?
(2) What do students feel are the similarities and differences between their experiences in the science classroom and the work of real-life scientists?

Methods

Participants

This study included five Grade 4 (students ages 9–10) classrooms from two schools that were part of a larger project aimed at enhancing and improving teaching scientific inquiry through formative assessment. The sample was roughly balanced between male ($n = 86$) and female ($n = 75$) participants. Both schools were high-performance schools in the national Primary School Leaving Examination, which is a placement examination for Grade 6 students to be emplaced in secondary school. Our rationale for choosing these two schools was to highlight how the students in high-performance schools viewed science and school science. Moreover, these students were considered to be more confident in learning school science and would have a relatively higher probability to further study science and pursue a science-related profession when they grow up. Grade 4 classes were chosen because we assumed that the students at this grade should be familiar with the laboratory environments and have developed some basic science process skills since, in Singapore, science is introduced as an academic subject for the first time in Grade 3.

Data Collection

As part of the larger project, we observed two science units, heat and matter, which were each five weeks long. All the classroom observations were video-recorded for further analyses. To probe how students visualise themselves as scientists and science students, we employed a student drawing activity, a questionnaire, and interviews. Drawings have been broadly used in educational research to access children's thinking and meaning making so as to document schooling and support change (Haney, Russell, & Bebell, 2004). Through drawings, children can make their ideas visible and also extract information from the educational context in which they find themselves (Weber & Mitchell, 1995). Moreover, it is considered that some children may have difficulties expressing their thoughts verbally, so the drawing can enable the nonverbal communicators to give us their impressions (Dove, Everett, & Preece, 1999). Therefore, the tool of 'drawing' was selected to document students' perspectives and to transcend assumptions regarding what is going on in their science classrooms. The drawing activities designed for this study were open-ended in nature, in which the students were asked to draw two pictures on an A3 size paper. In one picture, they had to draw and label themselves doing science in class. In the second picture, they were asked to draw and label a scientist who is doing science in real life. What is more, the students were encouraged to offer detailed written descriptions about their drawings at the bottom of the two pictures. The students were limited to about 30 minutes for the task, to reduce the risk of those finishing early copying or drawing inspiration from their classmates.

Following the drawing activity, the students were given another 20 minutes to complete a questionnaire, which included three sections of questions: (a) open-ended questions about students' most/least favourite academic subjects and their future career choice; (b) semi-structured questions about students' perceived roles of themselves as science students, their science teacher, and real-life scientists; and (c) 19 Likert scale items which measured student's interest in school science, science-related activities beyond school, self-efficacy in science, and science classroom experience. For this paper, we only report students' responses to two questions in the second section of the questionnaire: 'During my science lessons, I should . . . ' and 'At work, a scientist should . . . '

In order to further explore students' images of themselves relative to scientists and school science, interviews were conducted two weeks after administering the survey and drawing activities. In each class, six to eight students were interviewed individually based on the drawings they produced, which reflected different levels of traditional/progressive science classroom and stereotypical/non-stereotypical images of scientists. In total, 36 students were interviewed, including 20 girls and 16 boys. During the interview, students were shown their drawings as platforms that offer something concrete for them to talk about (Ehrlén, 2008). Our conversations with the students were open-ended with the purpose of inquiring into students' own perceptions of their science learning experiences rather than directing them to match their knowledge with that of the researcher. We started the conversation by asking students to describe their drawings and then used the following questions to guide the discussion:

- What kind of people can become a qualified scientist?
- Have you seen any scientists in your real life? Who are they? Where did you meet them? What were they doing?
- What do you like about science class? Why?
- Are you like a scientist in your science class? If yes, how? If no, why not?
- What types of things makes someone a good science student?
- What would you expect a good teacher do in your science class?

By providing students with an opportunity to talk about their school science experience and to clarify and confirm the intentions of their drawings and written statements, we aimed to get valuable insights into students' 'visual thought' (Brooks, 2005) of learning science as inquiry. Additionally, the triangulation of different data sources, including drawings, written responses to the questionnaire, interviews, and classroom observations further enhanced the construct validity of this study.

Coding and Analysis

The data corpus collected for this study were analysed by following an open-coding approach guided by the grounded theory approach (Strauss & Corbin, 1990), which allows researchers to 'generate explanatory propositions that correspond to real-world phenomena' (Patton, 2002, p. 489). Apart from the drawings and the questionnaires, classroom observation data and student interview data were transcribed verbatim and analysed for the purpose of triangulation.

Table 1. Student drawings: student doing science in class vs. scientist doing science in real life

Doing science as...	For students (%)	For scientists (%)
Hands-on work	60[a]	90
With research purpose/question(s)	25	39
Other actions		
Observing	7	15
Investigating	20	34
Inventing	1	21
Recording data	7	5
Group work	16.5	8
With discussion/communication	2.5	1
Learning from teacher	21	0
Completing workbook	15	3

[a]The overall percentage is more than 100 because student drawings may have more than one theme.

The coding schema for students' drawings and written statements about the drawings were initially adapted from previous studies based on the Draw-a-Scientist Test (Buldu, 2006; Chambers, 1983; Newton & Newton, 1998; Palmer, 1997) and further modified after a pilot study to best answer the research questions. For the main study, all the drawings and written statements that accompanied drawings were converted to electronic portable document format. Three main categories were identified for coding both 'student doing science in class' and 'scientist doing science in real life' drawings, which included the following: hands-on work (with or without clear statement of research purpose or questions), group work (with or without clear indication of communication), and other actions (e.g. observing, investigating, inventing, and data recording). Moreover, for the drawings of 'student doing science in class', another two categories were generated from the data coding process, including learning from the teacher and completing the workbook (Table 1). In total, 158 out of 161 drawings were considered as valid data based on the completeness and comprehensibility of the drawings. Two researchers independently coded all the valid drawings. Reliability was established for the actions of student and scientist schema with a Cohen's kappa of 0.88 (93% agreement). Remaining disagreements were resolved by discussion.

Students' responses to the second section of the questionnaire were analysed and different categories or themes for their perceived roles of science student, science teacher, and scientist were generated from the transcribed text (Appendix 1).

Findings

How Students View Their Experiences in the Science Classroom

The students in our study had developed complex views on science and school science. However, what the students told us about themselves doing science in class and scientists doing science in real life shows that their naiveconceptions about what scientists do affect how they view their classroom experiences. Our analyses revealed four themes, representing how the students related themselves to science and school science (Table 1). These themes included 'doing science as doing hands-on investigations', 'doing science as a social process', 'doing science as learning from the teacher', and 'doing science as completing the workbook'.

Doing science as doing hands-on investigations. As shown in Table 1, about 60% of the students drew themselves doing hands-on experiments alone or with classmates. However, only 25% of them offered some information about the experiments, such as the purpose of the experiment or research questions, either through drawings or written descriptions. This result was within our expectation, because nearly all the students we had interviewed stated that doing experiments was a fun part of their science class. However, in their drawings of scientists doing science in real life, 90% of the pictures showed scientists conducting experiments and 39% of them gave relatively detailed descriptions about the purpose of these investigations.

Figure 1 is an example that shows how students viewed doing science in class as conducting hands-on investigations. In this picture, Sharon drew her and her classmates doing an experiment about heat and described that: 'Our aim of the picture was to make the bottle expand and return to its norm form after being crushed by our teacher. While I was performing the experiment, my group members would jot down the observations.' It is interesting to note that Sharon only drew the hands of her group member and herself without offering their facial images by emphasising the experiment they are working on. In the picture, Sharon is holding a squashed plastic bottle and the dotted line with an arrowhead indicates that she is going to put the bottle into the hot water. Her group member (another girl) is shown

Figure 1. Sharon's drawing of herself doing science in class

holding a pencil and clipboard in her hand, presumably writing. It appears that the students can assign themselves into different roles (material operator and data scribe) during hands-on investigations.

Similar to other students in our study, during her interview Sharon expressed that doing experiments was one of the most interesting parts of her science lessons. Upon further probing, she stated:

> We always have to make predictions and predictions spoil the fun that we get to, get to have when we discover . . . Because, like, when you predict you already have an expected outcome, but if you don't predict you can learn more.

Although the student understood some basic processes of conducting an experiment, such as observations and data collections, she did not recognise that an authentic scientific investigation usually starts from a hypothesis. In fact, in our interviews with the 36 selected students, only one of them mentioned making predictions as a component of doing science for both students and scientists.

Doing science as a social process. The analyses of data showed that about 60% of the pictures included only the students themselves, which might have been expected from the directive 'draw *yourself* doing science in class' (emphasis added). The content of these pictures varied, from a student simply sitting on a chair reading or writing to engaging in scientific practices with a range of materials, for some particular purpose. For the pictures that included other people (38% of the pictures), such as classmates and/or science teacher, it was interesting to note that 16.5% of the pictures demonstrated student group work (Figure 1) but only around 2.5% of the pictures

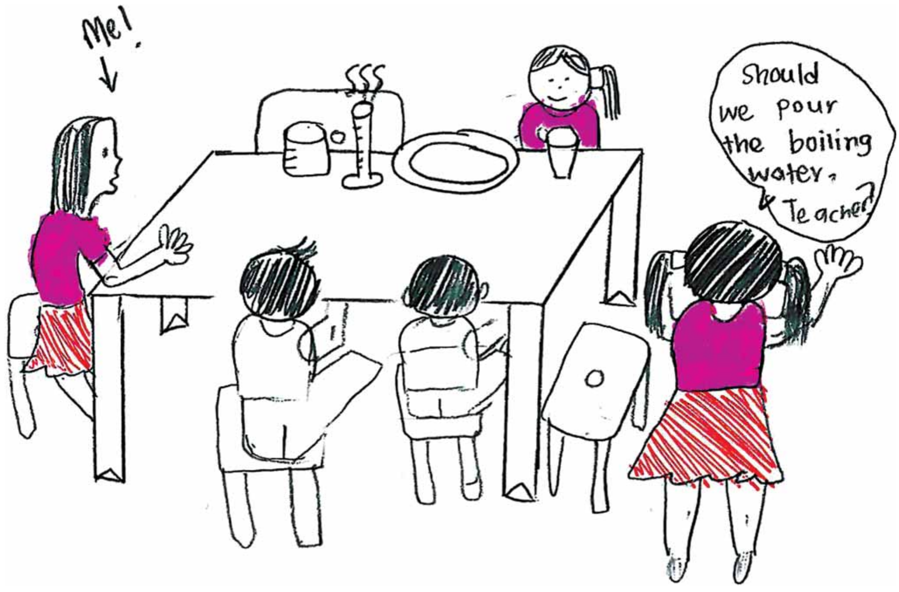

Figure 2. Anusha's drawing of herself doing science in class

(4 out of 158) portrayed students discussing or communicating ideas during group work (Figure 2). For the drawings of scientists doing science in real life, only 8% of them had any indication of group work.

In the picture above, Anusha drew herself as the co-actor engaged in a group experiment in a science laboratory setting. She wrote that 'My group is doing an experiment on heat topic and we are discussing how to conduct the experiment.' In the picture, a group of five students are observing the hot water in a measuring cylinder, and one of them raises her hand and asks their teacher for help—shall they pour the boiling water? It appears that the group have an emergent issue with their on-going experiment and request procedural information from their teacher. Although the picture does not show group discussion explicitly, we can infer that the students reach the decision to ask teacher for help after communicating their own ideas within the group.

During her interview, Anusha told us that: 'Because it is science lab, my whole group sit together . . . Sometimes my friends and I always pretend be a scientist. [And ask] shall we do this, shall we do that? So that becomes more fun.' It seems that the laboratory setting enabled the students to work in groups with more discussion to take place. In addition, during our conversations with other students, many of them also used 'we' statements to describe their science classroom activities. This reveals that the students can see themselves as shared members of a classroom community and achieve meaning making through discussion and communication with other members.

Doing science as learning from the teacher. Despite the fact that the majority of students pictured themselves actively engaging with hands-on science, we also noted that about 21% of the pictures depicted students passively listening to their teacher talk or watching the demonstrations operated by their teacher. In this regard, not all students viewed themselves as active participants but rather as peripheral participants who were bounded by specific actions of their teacher. Throughout our classroom observations, we found that in many classes, the classroom discourse was dominated by teacher's lecturing type of talk and for safety and time issues some experiments were conducted by the teacher as demonstrations. Thus, it is reasonable to have some students consider learning from their teacher as an important perspective of doing science in school (Figure 3).

As shown in Figure 3, Lawrence drew two pictures about doing science in class and described the pictures as: 'In the lab, we are doing an experiment. The teacher is explaining and we are watching and listening. In classroom, the teacher is teaching and we are taking down the notes.' The first picture on the top depicts a science lab setting, where a group of students are watching a demonstration and listening to the instructions or explanations offered by their teacher. It looks like that the teacher's speech represented as 'blah, blah . . . ', illustrates a stereotypical didactic teaching scenario. For the second picture at the bottom, it appears that in the classroom the teacher is explaining and the students are copying down the notes in the classroom. Of note is the fact that both pictures show students facing the teacher from left to

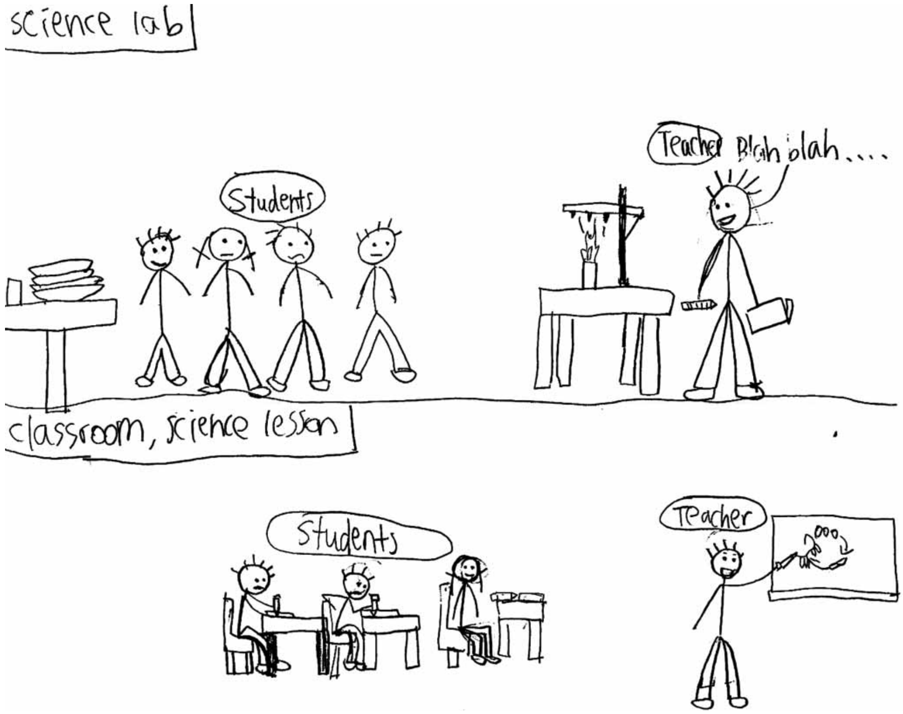

Figure 3. Lawrence's drawing of himself doing science in class

right and listening to what the he is saying, which depicts a traditional classroom setting, that is, teacher fronted with students as passive recipients of knowledge. Likewise, the teacher in the top picture is holding a book, while the bottom picture shows the teacher drawing a model on the board. This provides further evidence that the teacher is viewed as the source of knowledge.

During the interviews, 10 out of 36 students, including Lawrence, told us that in their science class what they need to do is to listen to the teacher's instructions and then do what they are told to. It is reasonable that students can view themselves as attentive participants in the community of the science classroom and show their respects to the teacher. However, these students may also view themselves as passive recipients of factual knowledge from the teacher without actively participating in questioning, designing experiments, developing explanations based on evidence, and communicating their findings. Moreover, some of these students ($n = 6$) also told us that they would not want to pursue a science-related career when they grow up even though science was their most favourite subject and they were very good at it. It appears that the students' learning experiences in their science classroom were affecting their aspirations in learning and future career choice.

Doing science as completing the workbook. Approximately 15% of the students drew themselves completing the workbook during a science lesson, which is three times

Table 2. Students' responses to the roles of a good science student and the roles of a qualified scientist

Expected roles	A good science student (%)	A qualified scientist (%)
Well behaved	94[a]	54
Learning for knowledge	10	2
Seeking understanding	8	24
Dedicated and hard-working	4	21
Applying knowledge	0	11

[a]The overall percentage is more than 100 because students' statements may have more than one theme.

more than the drawings of the scientist who is completing the workbook when doing science in real life. We observed that the use of the workbook was a common practice in these students' science classrooms, either functioning as a worksheet for recording experiments or an assessment paper for consolidating content knowledge. During the interview, one of the students who drew themselves completing the workbook during a science period said that: 'I write on the workbook so I feel like a kind of mini-scientist.' It is surprising that the student viewed completing the workbook like what a scientist does. Perhaps '[s]uch work would recognise the central role of writing as a means of learning ideas, and not solely as a means of producing a record of work done' (Millar & Osborne, 1998, p. 24).

Roles of a Science Student and Roles of a Scientist

To identify how students compare themselves with scientists, the questionnaire asked students to state the expected roles of science students and scientists. According to the coding of survey data, five themes were identified, including 'well behaved', 'learning for knowledge', 'seeking understanding', 'dedicated and hard-working', and 'applying knowledge' (Table 2). During our analysis, we actively sought both commonalities and differences in students' responses by gender, teacher, and school, but there were very few differences evident.

We noticed that about 94% of the students considered regular classroom behaviours, such as paying attention, following instructions, being quiet, and so forth, as being part of what a student should do in a science classroom. In contrast, only about 54% of the students expressed that scientists should be well behaved, such as being responsible in the laboratory, being serious when doing experiments, and listening to the supervisor. It is apparent that the students' statements regarding what they are expected to do in a science classroom are not very different from what they should do in the classroom of other subjects. However, their views on what a scientist should do are more specific and related to science. For example, students mentioned that scientists should be careful when doing experiments and need to 'watch out for anything dangerous', 'wear safety equipment', and 'not burn their hands'. More specifically, a female student stated that scientist should be brave and she noted that: 'You must also be brave that you must know that you're going to get injured by some kinds of chemicals' (Clare, 20/07/2012, C2).

The next most expected role of a good science student is learning for knowledge. Approximately 10% of the students articulated that copying down the notes from their teacher, memorising the facts presented in the class, and answering the teacher's questions are significant things they need to do to learn about science. For example, some students expressed that they should: 'Focus on the questions and answer them;' 'Take down notes to remember and revise;' and 'Remember what teacher said.' Again, these elements are not very different from what a student in other subjects is expected to do. However, only about 2% of the students responded that scientists should learn for knowledge.

Compared to the view that a scientist should learn for knowledge, a larger proportion of the students (24%) expressed that scientists are supposed to seek understandings about the world. For instance, some students responded that a scientist should 'try different methods when conducting an experiment' and 'prove things right through research'. In contrast, only 8% of the participants believed that a science student should develop understandings during a science lesson through questioning, writing notes, and investigations.

In addition, approximately 21% of the students thought a qualified scientist should be dedicated and hard-working. Some students put that scientists should 'do their work properly and learn from their mistakes', 'recheck their work and never give up', and 'be confident even failed an experiment and try it 100 times more until it works'. However, similar statements were rarely found in students' response to what they should do in class, as only 4% of the students considered working hard as an important construct of the expected role of a good science student.

Finally, approximately 11% of the students stated that scientists should apply knowledge so as to invent new things to help people. Some students expressed that, for example, a good scientist should: 'discover something useful that can help people', 'find a cure for cancer', and 'explain to public what he found so we all can get to know things better'. In contrast, no one mentioned that science students should apply what they learned to practise. Therefore, during the interview, we prompted students to elaborate on what makes someone a good science student. Nevertheless, students still mostly mentioned good behaviours and when pushed, some of them talked about learning for knowledge or being hard-working rather than mentioning seeking understanding or applying knowledge.

How Students Are and Are Not Like a Scientist in Science Class

In order to explore similarities and differences between students' experiences in the science classroom and the work of real-life scientists, during the interview we further probed students about how they were like/not like a scientist in their science classroom. Twenty-six out of 36 students offered a tentative response about whether they were acting like a scientist in their science classroom, by stating

Table 3. Students are like/not like a scientist in class

Students feel they ARE like a scientist in class, because ...	Students feel they ARE NOT like a scientist in class, because ...
• They do experiments	• They are not allowed to do dangerous experiments • Scientists' works are more complex
• They think mathematically	• They work in groups and assisted by the teacher; real scientists work alone • They must listen to the teacher or follow their workbook

'maybe', 'a bit', or 'sort of'. Another six students answered 'no' and four said 'yes'. Table 3 summarises the reasons why students found themselves acting like and not like a scientist in class.

Nearly all the students who thought they were acting like a scientist in class explained their reasons for holding such a belief by mentioning that they could do hands-on experiments. Conversely, a female student responded that: 'It's really cool you get to touch all the cool things and just be like a scientist,' but 'There's more fun when we make observations and then take down notes.' When we further probed her about why she thought recording data is like what a scientist does, she expressed that: 'I jot down many notes like what's happening and what I think is going to happen to make sure that my experiment will turn out the way I expected.' It is interesting that the student highlighted that the purpose of making observational notes was to help her further think about the experiment and predict what would happen. As we pointed out earlier, students (e.g. Sharon) normally did not recognise the importance of making predictions in doing science, but this student found that the inquiry elements of making observations, recording data, and generating hypotheses made her feel like a scientist in her science classroom.

In addition, one student expressed that he was acting like a scientist because he needed to think mathematically to conduct an experiment. When asked to talk about the drawing of himself doing an experiment of how stones occupy space, the student pointed out that: 'If you want to be more scientific you need something else. You need to be mathematical, because science you need to check how, like this picture, for example, how much space these stones occupied is a mathematic thing.' According to this student, science and mathematics are interrelated and doing science requires mathematics and computational thinking for problem solving.

Students' reasons on explaining how they were not like a scientist in class varied. Most of them expressed that in class they need to listen to their teacher and follow the instructions stated on the workbook. Some other students reported that in class they were not allowed to work on chemicals like what scientists do, as a student explained, for instance, 'Our teacher said we are too young to touch them.' Furthermore, scientists' work was considered as more difficult and complex and doing science in class was only, as a student stated, ' ... do the experiments that have already been found out'. This notion demonstrates that students can recognise that 'real' science is to discover the unknown and school science is already known. Also, a few students thought that scientists work individually and have to solve problems on their own, but doing science in class involved group work and help from the teacher. Interestingly, one student articulated that he was not like a scientist in school science class but that he was like a scientist when he was on a school trip to a botanic garden. He explained that in the classroom he just listens to his teacher and copies down the notes, but in the botanic garden he could interact with different plants directly through observing, touching, smelling, and even tasting, which made him felt more like a scientist.

Discussion

In this paper, we set out to answer two research questions. The first question relates to the students' views on their experiences in a science classroom. It was evident that tension could exist in students' views of their school science learning experiences. In their drawings, although most of the students depicted themselves engaging with hands-on experiments in their science classroom, they did not usually express a research question or a purpose of an experiment. The students merely emphasised the hands-on aspect of experiments while other aspects of inquiry, such as generating scientific-oriented questions, developing evidence-based reasoning, and evaluating findings, were missing from their pictures and descriptions of their classroom experiences. It is apparent that hands-on investigations are important approaches to engage young children with science (Hofstein & Lunetta, 2004), but simply viewing doing school science as a hands-on rather than minds-on activity indicates that the students in this study did not possess a clear understanding about the nature of scientific inquiry (Meichtry, 1992; Moss et al., 2001). Although research has shown that hands-on activities contribute to students' interest in learning about science (Gibson & Chase, 2002; Roberts & Wassersug, 2009), it is critical to have students 'to interact intellectually as well as physically, involving hands-on investigation and minds-on reflection' (Hofstein & Lunetta, 2004, p. 49) because 'observation and experiment are not the bedrock upon which science is built; rather they are handmaidens to the rational activity of constituting knowledge claims' (Driver, Newton, & Osborne, 2000, p. 297).

Furthermore, a number of students in this study felt that in order to be a good student in science they must be well behaved and remember everything they had been taught. This result is similar to what Shanahan and Nieswandt (2011) and Varelas et al. (2011) have found. However, unlike the students in our study, Shanahan and Nieswandt's (2011) students reported that apart from being well behaved, science students have a dynamic role, including being creative, intelligent, skilled in science, and scientific. One potential reason for this difference is that the students in Shanahan and Nieswandt's study were from Grade 10 and thus more experienced in science learning than the students in our research. When prompted further during interviews, most of the students in this study rarely talked about applying knowledge or exploring their own ideas. It seemed that the students' ideas about doing science were related to what doing school involved, which is in line with what Varelas et al. (2011) have found in their research on a group of African-American children's identities in science. It is arguable that when teachers possess a misconception about teaching science as inquiry by giving priority to content knowledge and experimentation, they focus on students' good behaviour. As Varelas et al. (2011) have pointed out, 'children brought up behavioural norms as dimensions of doing science may mean that they had constructed the view that unless they behaved well they would not have access to science, and would be invisible, outsiders, and left out' (p. 846). The infusion of conceptions of doing science into conceptions of doing school also reveals the authoritative role of the teacher. For instance, some students such as Lawrence in our study depicted a teacher-centred, text-book-oriented science learning environment, where the students have limited opportunities to conduct scientific inquiry.

The second question to be answered was 'What do students feel are the similarities and differences between their experiences in the science classroom and the work of real-life scientists?' To this question, the survey and interview data showed that young children can make a clear distinction between school science and science done by scientists, which is consistent with what Archer et al. (2010) have found. However, it was a bit disappointing that most of the students in our study reported that they were like a scientist in class just because they did experiments (Varelas et al., 2011), the points expressed by two students that doing mathematical thinking and making predictions like what a scientist does were enlightening. According to the US National Research Council (2000, 2012) documents, mathematical thinking and developing hypotheses are significant components for doing scientific inquiry and they are also what science teachers should promote during their inquiry-based science teaching practices. Additionally, students such as Anusha pointed out that the laboratory setting enabled them to have peer discussions and share thoughts. According to our observations, students usually sat in rows and faced the whiteboard when learning in the classroom. In this regard, the organisation of a science classroom should promote peer collaboration and social interactions, through which students can develop an understanding about the nature of a specific community of practice, such as science (Varelas et al., 2011).

In this study, students possessed more positive attitudes towards scientists by highlighting that a qualified scientist should seek understanding, apply knowledge, and work hard, rather than emphasising that the scientist should be intelligent like a 'boffin' (Archer et al., 2010, p. 632). However, the students in our study had some misconceptions about scientists and their work, First, students believed that science is dangerous. Previous research has already reported that students consider scientific practice as a dangerous work by many female students (Osborne & Collins, 2001). This masculine view of science can, as Archer et al. (2010) have argued, negatively affect students' attitudes towards science and discourage them from becoming a scientist. In addition, students in our study reported that scientists work alone and usually solve problems on their own. In fact, this a prevailing misconception held by many young people from different countries, social, and cultural backgrounds

(Chambers, 1983; Newton & Newton, 1998). Research has implied that this misconception is related to the influence by popular media, such as cartoons and movies, as well as students' lack of experience to have direct interactions with scientists (Song & Kim, 1999).

The findings of this study point, we believe, to several considerations for practice. First, although teaching science as inquiry has been promoted for a few years at the primary school level in Singapore, our research findings suggest that more work needs be done to address the teaching of science as inquiry through inquiry-based pedagogy. Instead of teaching content knowledge for examinations, science teachers need to attend to students' conceptual understanding about science. Thus, apart from teaching the content knowledge of science, teachers can also spend time nurturing the spirit of inquiry by promoting student-generated questions (Chin & Osborne, 2008) and giving priority to evidence to facilitate the development of scientific reasoning (McNeill & Krajcik, 2012). In addition, teachers need to recognise that the reciprocal approach to science teaching cannot promote scientific inquiry and develop NOS understandings. In this regard, learning activities in a science classroom should be student-centred, where the teacher plays a guiding role to help students understand the logic behind producing scientific knowledge apart from acquiring knowledge of the products of science and their use (Gyllenpalm, Wickman, & Holmgren, 2010). Since many students held misconceptions about scientists, this study suggests that the teaching of science as inquiry should be embedded into the teaching of science by inquiry, particularly by addressing the NOS more explicitly.

A more recent study conducted with primary school teachers in Singapore has found that many teachers misunderstood the meaning of scientific inquiry by privileging content knowledge over students' explanation, discussion, presentation, and communication (Kim, Tan, & Talaue, 2013). In addition, the overemphasis on the teaching of science content using experimentation would result in learning experiences that ignore how science knowledge is formulated, and why we choose to believe the knowledge as presented to us (Tan & Wong, 2012). The fact that the students in our study possessed stereotypical images of learning school science, such as learning from the teacher, might relate to their teachers' understandings about scientific inquiry. As Kim et al. (2013) have argued, teachers' misconception about scientific inquiry would influence their instructional choice by adopting a didactic pedagogical approach similar to what we observed in this study. In this regard, this study suggests that teachers need to develop a clearer understanding about the nature of scientific inquiry during both pre-service training and in-service professional development (Anderson, 2002; Flick & Lederman, 2004).

Furthermore, this study shows that students' misconceptions about scientists and their work still persist. It is arguable that school science should address what it means to do real science to students because this shapes their views on their science classroom experiences and affects the development of their identities in science (Varelas et al., 2011). In this regard, science teaching should not be constrained by the narrow curriculum and limited information in the workbook or teacher guidebook, although they are designed based on the principles of inquiry and NOS. Instead, teachers should encourage students to pose questions that are anchored in real-life problems they are familiar with and develop appropriate solutions through collaboration and negotiation so as to create a more authentic science learning environment (Rahm et al., 2003). For instance, learning beyond the classroom, such as school trips to science museums, botanic gardens, and zoos has been found to be effective alternatives to promote students' positive attitudes towards science (Braund & Reiss, 2006), because in these settings students can explore their own ideas through dynamic interactions with scientific exihibits, teachers, peers, and scientists (DeWitt & Hohenstein, 2010a, 2010b; Zhai, 2012).

Limitations and Further Research

The main limitation of this study is that it mainly relies on student self-reports, which may not allow students to fully express their views of their science classroom experiences. Moreover, as learning is a social process and situated in context (Lave & Wenger, 1991; Vygotsky, 1978), further study will need to be done to investigate the interactions among members of the science classroom community, where students as the new comers and teacher as the master practitioner. As part of our data corpus, we also have videos of a number of lessons from each classroom, thus the microanalyses of classroom discourse, especially how teacher and students negotiate their roles during teaching and learning practices, may guide us to develop an in-depth understanding about how students develop their identities in science and what factors may influence and shape such a process. Another limitation of this study is that the students were recruited from high-performing schools in Singapore, thus our findings are contextualised and cannot represent the views held by students at other schools. Further research will include students from both high- and low-performance schools and compare their images of learning school science. This may enable us to investigate how contextual factors, such as academic abilities, self-efficacy, school culture, and so forth, influence students' views about school science and the work of scientists. Last but not least, this study only explored students' ideas about themselves doing science in school and scientists doing science in real life. It will be interesting to investigate the origins of these ideas in our further study.

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Note

1. We have recognised the difference between the definition of inquiry and scientific inquiry, that is, the latter one emphasise inquiry in the domain of science. For the readability, however, this paper used inquiry and scientific inquiry interchangeably.

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Appendix 1. Codes Identified from Students' Responses to the Questionnaire Questions

Science Student's Roles

- Well-behaved: listen to teacher, pay attention/be concentrate/be focus, follow instructions, be careful, be quiet
- Learning for knowledge: learn, remember, understand, copy notes, answer questions, be specific
- Seeking understanding: questioning, experimenting/investigating, observing, recoding notes
- Dedicated and hard-working: willing to work hard, to get high scores, actively participated in some activities
- Other: different from the above categories

Scientist's Roles

- Well-behaved: lab management, be safe, be serious, focus, listen to boss
- Seeking understanding: questioning, experimenting/investigating, observing, recording data
- Dedicated and hard-working: willing to work hard, thinking, check facts, planning, never give up, learn from mistakes
- Applying knowledge: help people, invent/create
- Knowledgeable: know everything, be smart
- Other: different from the above categories