'Let's think like a scientist!': Issues of school science

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ABSTRACT
The nature and purposes of science education in Singapore have been, for a long time, an area of debate and concern. Ask teachers, curriculum developers, policy makers, science education researchers, scientists or students about the nature and purpose of science education, you will undoubtedly receive many different answers. The issue of interest here is the understanding of what nature and purposes of science education are among some teachers and students in Singapore. In this paper, we problematize the notion that high school students can think and should be able to think like a scientist. We hope that the discussion generated in this paper will contribute to an increased awareness among teachers and researchers about the issues relating to the nature of school science, learning science and the practices in the science classroom. This study examines two students from a class of 23 girls and their perception of what science is together with their biology teacher in a secondary school. In one of the classroom transcripts, the teacher reminded the students several times to 'think like a scientist!". This prompted us to question if the assumption that everyone knows how a scientist operate is valid. In this paper, we attempt to use Membership Categorisation Analysis (Freebody, 2003; McHoul and Watson, 1984) to provide insights into some ideas about science which the teacher and two students from the same school community have explicated. Their interview transcripts constitute the main data source in this paper. The results of this study revealed the complexities of issues relating to the introduction of the notion of nature of scientific enterprise in the secondary biology classrooms.

Strand: Teaching and Learning
Key Words: *Nature of Science; Membership Categorisation Analysis*

INTRODUCTION

This paper presents the dilemma created when drawing a parallel between contemporary world of science and school science. The dichotomy that we present here, however apparent, is deliberate so as to show the tension that exists between two seemingly similar domains of knowledge and practices but yet can be potentially different at the same time. To begin our discussion, let us examine the purposes of school science and contemporary world of science. Caravita and Hallden (1994) discussed the purposes of the scientific enterprise as a search for scientific knowledge. This search, according to Caravita and Hallden (1994, p94) is *'intentional, specialized, self-regulated, creative practice involving a community that shares goals, motivation, professional tools (mental and materials), codes of communication, and epistemic values.'* The purpose of school science, on the other hand, is one whereby the syllabi determine and dictate what scientific knowledge the students will learn – to transmit the scientific knowledge generated by the scientific community to learners. The search for scientific knowledge by the students is unlike that of scientists as the intended outcomes are usually dictated by what they are presented with by the teachers and the science curriculum of the school. For example, students in Singapore are not at liberty to decide what they would like to learn or discover during science classes. What they learn in primary school is determined by the primary science syllabi which are set by the Curriculum Planning and Development Division which stated that the science education in Singapore at the primary level aims to provide students with foundation for higher levels of science learning in secondary schools (Curriculum, Planning and Development Division, 2006). At the secondary school level, the goal of the science curriculum is to provide a platform of learning for students to pursue science at the junior college level. The overarching goal of science education in Singapore is to prepare students to be *'sufficiently adept as effective citizens, able to function in and contribute to an increasingly technologically-driven world.'* (Curriculum Planning and Development Division, 2006). Compared with the focused and 'intentional' search for scientific knowledge in the contemporary world of science, school science is presented with 'ready made' knowledge which is then packaged to be presented to the students at different levels. The knowledge that is presented in school science appears to be less exploratory and more factual. Further, school science knowledge is usually presented in an environment that is removed from the original context from which the knowledge is designed. While contemporary science aims to ‘discover’ and construct new knowledge to explain the various phenomena around us, school science aims to inform students about what these knowledge are.

With different intended outcomes, seeing the science learner as a scientist becomes problematic. The question we would like to raise here is whether there is alignment between the process of science knowledge acquisition and the process of formulation of scientific theories throughout the history of science. Is it a futile exercise for us to be looking at the parallel between how students learn and how scientific theories are developed? Besides serving different purposes, it appears that the context in which these two types of knowledge are formulated is also different. In the contemporary world of science, scientists work as a community of practitioners, striving towards a common goal of discovery and problem solving. There are social norms and rules which are accepted, understood and refined continually by members in the community. These social rules ‘govern’ behaviour and practices within the scientific community. The acquisition of scientific knowledge in schools is not governed by the same social norms as that in the scientific enterprise. Schools are often not structured like the scientific research communities. Rather, the learners are sometimes perceived as ‘ignorant’ recipients of knowledge (Tan, 2006). Students and teachers may not be working towards a common goal of discovery and problem solving as teachers and students play different roles in the activity of teaching and learning. Edwards and Mercer (1987) found that most of what students learn in schools is predetermined by the curriculum, and hence, the nature of education is merely a process of socialisation into the pre-existing epistemological world. If we extrapolate this idea to compare contemporary world of science and school science, we argue that science teachers will then need to be ‘socialised’ into the practice of contemporary science before they can successfully socialise the students into the intellectual and cultural traditions of science. The issue of concern here is whether science teachers have the capacity to socialise the students into the contemporary world of science when they might not have had the experience themselves. Socialisation is complex and entails long term immersion and practice within a particular culture. We argue that teachers as ‘experts’ are different from scientists as ‘experts’ as they are from different ‘communities of practice’ and hence are initiated into different norms, practices and knowledge, and there are different goals set for these two enterprises. Hence socialisation of science teachers is not equivalent to socialisation of scientists. The discussion above highlighted some of the obvious and important differences in social norms and rules in knowledge acquisition in school science as compared with contemporary world of science.

In Singapore, where the dominant pedagogy is teacher-centred and routinised, (Luke, Cazden, Lin & Freebody 2005), it will appear to be pretentious to assume that school science classrooms and laboratories are structured like research laboratories and communities in the contemporary world of science and hence a curriculum can be designed based on these assumptions. It is also futile to try to improve science education by simply focusing on teacher competences in science alone. Rather, we argue, there is much to gain from examining ideas which science teachers and students might have about *what* school science is and how these ideas about school science affect their perceptions about the social norms in learning science in schools, roles and identities they take on in schools. So far, little attention has been paid to how teachers see the world, that is, how teachers as individuals think about how the world works around them. Teachers’ ideas and beliefs have impact on the way they carry out their practices in the classroom. Tan (2006) showed how teachers’ ideas about the way knowledge across two different topics of biology impacted their planning and shaped the kinds of interaction that is possible in the classroom and laboratory. As a consequence of this direct influence of their ideas on actions, there is a need to examine these ideas, albeit deep seated, to surface reasons to explain why teachers do what they do. These ideas are valuable and crucial in helping researchers and practitioners alike make sense of and understand the underlying reasons for what goes on in classrooms where science is discussed.

The key purpose of this paper is to use Membership Categorisation Analysis (henceforth, MCA) to provide insights into some ideas about science as explicated by a teacher and two students in a particular school community.

METHODOLOGY

Data Collection

This study is carried out in a premier all girls' school situated in a privileged neighbourhood in Singapore. The students in the study belong to the top ten percent of their cohort as evidenced from their performance in the Primary School Leaving Examination (PSLE), a national placement examination that all students sit for at the end of six years of primary school education for placement in a secondary school. The class understudy comprised of 23 students with an average age of 15 years old. The teacher in the study, Brenda (pseudonym), is an experienced teacher with 19 years of teaching experience, 12 years of which is in the school understudy. She is passionate about her work and is constantly working to innovate her practice.

The school was chosen for this study as they are one of the few schools in Singapore that has a science curriculum which explicitly addresses nature of science. The students in the school have to attend two modules in consecutive years, each lasting 10 weeks on the nature of science. These modules are taught when the students are 13 and 14 years old. This unique arrangement places the school in a position to be more 'advanced' in their science curriculum and hence practices in the school are of value to study because it allows for further study of how the students' notions of school science and contemporary science affect their understanding of the nature of science, a curriculum focus which is not found in other schools.

Lessons conducted by Brenda, both in the classroom as well as the laboratory were observed. Field notes, video recording and audio recording were collected for each of the lesson. Two surveys were carried out with the pupils, one at the beginning of the term and the other at the end of the term, 10 weeks later. Two interviews were conducted with the teacher and one interview was conducted with five selected students. An interview is used as a means of data collection as it is the usual way in which the ideas residing in people can be sought and determined. Interview offers a means of accounting for actions taken by different individuals. In this paper, we assumed that the teacher and the students already have pre-existing knowledge about science before the interview and these are the ideas that we try to understand. All audio recordings were transcribed for analysis. For this paper, only the findings from the interviews of the teacher and two students are presented and discussed. The interviews of the two students are chosen as they are representative of views expressed by the five students interviewed. These findings provide the basis for our future study on how the ideas possessed by teacher and students about school science can have an influence on their classroom practices.

Data Analysis

To understand the teacher and the students' ideas about school science, the interview transcripts are analysed using principles of Membership Categorisation Analysis (MCA). Sacks (1995, p40), theorised that the knowledge which members of a community hold are usually put into categories and hence *'by examining the categories members of the society/community refer to, one can 'infer' a great deal of life and practices of the society.'* Further to Sacks, Freebody (2003; p156) defined MCA as a '*way of explicating how speakers draw on and reconstruct common cultural sense in specific situations*.' Similarly, membership categories, according to McHoul and Watson (1984, p284) are *'essentially terms used in the identification, description or referencing of persons.'* McHoul and Watson later extended categories beyond reference to people to places and phenomenon. In summary, MCA is a form of reasoning practice.

In this paper, we use MCA to get a sense of what is being said by different people. The unit of analysis used here is what the teacher and the students' say about the nature of school science. Here we examine how commonsense ideas which the teacher and students, as a community, hold about school science shaped their interaction and hence the formation of formal knowledge in science (in this case, specifically, biology). Researchers have used MCA to analyse both what is said during interviews (Freebody, 2003) and what is said during classroom interactions (McHoul & Watson, 1984). In this paper, we will use MCA to analyse both interviews to reveal what the teacher and students think about science.

ANALYSIS OF DATA

To begin our data analysis, we selected an episode during an interview with Jona (pseudonym), one of the students in the study. In excerpt 1, Jona was asked about her views regarding how her process of formulation of scientific knowledge has changed through time. In her answer, she revealed that she perceived school science and science as practiced by ‘real life scientists’ as different.

Excerpt 1: Very general and textbook based

R Ok. Alright. Now does your view of how scientific knowledge comes about change over the years? Say when you were in primary school and now?

S Yah because in primary school I didn’t have much idea of what was going on because ***primary school science was very general and textbook based whereas in secondary school erm they have activities that make you think like the scientists, like the cube activity*** we had. We were given a cube and we had to guess what was at the bottom. And from there there were activities that ***help us know how scientists think***. And during the activity some people cheated by peeking at the bottom because there was a paper at the bottom. So ***it shows like in real life some scientists go through underhanded means to find out to come to a conclusion***. But others, guessed and observed from the numbers of the cube, try ***to infer try to observe a pattern and make an inference on the pattern.***

Table 1: MCA according to Jona

Category	Membership Categorisation Device	Category Bound Activity
Primary school science	How personal scientific knowledge is learnt	Very general textbook based activities (line 4) Facts oriented (line 4) Source of knowledge is textbook based. (line 4)
Secondary school science	How personal scientific knowledge is learnt	Activity to think like scientists (lines 5-6) Process oriented (line 5) Source of knowledge is people-oriented (line 10)
Real life scientists	How scientific knowledge is formed.	From observations and inferences they use theories as a framework to build a conclusion about something. (referred to earlier in the transcript)

For Jona, school science can be categorised into two different types each having their own category bound activities. Primary school science is characterised by very general textbook bound lessons unlike secondary school science which is marked by activities which allow the learner to think like scientists, as in the cube activity. Primary school science is also facts-oriented while secondary school science is more process-oriented. The textbook serves as the primary source of knowledge for primary school science while in secondary school science, knowledge is perceived to be more people oriented as it is dependent upon people who ‘*try to infer try to observe a pattern and make inference on the pattern.’* (see lines 12 and 13 of excerpt 1). Jona also highlighted how *‘real life scientists’* formulate scientific knowledge. This categorisation by Jona falls under the device of how scientific knowledge is formulated. She focussed on the processes in which scientific knowledge is acquired. We note here that the category bound activities for school science appear to consist of activities which are ‘done to her’, compared with ‘*real life scientists’* who carry out observations and inferences, albeit on their own accord. Jona’s assessment of the activities relating to primary school science and secondary school science suggested that primary school science is less demanding cognitively as compared with secondary school science which requires her to ‘*think like a scientist’.*

Excerpt 2 shows a segment of a transcript of an interview with another student, Kathy (pseudonym). When the question of scientific knowledge was posed to Kathy, like Jona, she highlighted her personal science learning experiences.

Excerpt 2: Teacher say you write down

R Ok how does, this particular view of how scientific knowledge comes about change over the years? Say Like from primary school to now or is it the same all along?

S It does for a certain extent changed. Now I really found out what a theory means in biology which I did not know before.

R Before when?

S In primary school. In primary school I always thought a theory is just a guess. I just thought it means a guess. But right now theory is something that can be proven but it is still not definite but can be proven to be true.

R So that means your views of how science comes about changes when you come into secondary school? Is there any specific reason why it changed? Or what leads to the change?

S I think the reason will be that here in [school's name] we have much ***more resources to work with and in a way the teachers are much more knowledgeable than the primary school teachers that I had and also it is much more experimental. In primary school we didn't do that much of experiments. It is only like teacher say you write down. But now we can try it out to see if it is really like that***.

Table 2: MCA according to Kathy

Category	Membership Categorisation Device	Category Bound Activity
Science learnt in primary school	How personal scientific knowledge is learnt	Teachers say you write down. (line17) Teachers less knowledgeable. (line 15)
Science learnt in secondary school	How personal scientific knowledge is learnt	Teachers more knowledgeable. (line 15) Experiments to try out to see if it is really like that. (lines 17-18)

For Kathy, she did not refer to scientific knowledge as '*primary school science'* but described it as *'science in primary school'*. This form of reference, we argue, appears to suggest that for Kathy, scientific knowledge is a single enterprise and the difference lies in how the scientific knowledge is realised in primary school and in secondary school. This is unlike Jona who used the terms '*primary school science'* and *'secondary school science'* which we infer is likely to indicate that the nature of scientific knowledge at the two levels are perceived to be different.

Science that is taught in primary school for Kathy is characterised by taking notes of what the teacher said. In her view, the teachers dictating the scientific facts are less knowledgeable when compared to the teachers teaching science in the secondary school. This comparison of the knowledge level of teachers teaching in primary school and secondary school is similar to Jona's account of primary school science being cognitively less demanding as compared with secondary school science. Also, unlike the passive character of science taught in primary school, the process of learning science becomes active in secondary school. Here, experiments are performed to affirm the scientific knowledge presented. There is parallel between Kathy's and Jona's views that primary school science is less process-oriented as compared with secondary school science. However, unlike Jona, there was no mention of a category of 'real life scientists'.

Excerpt 3 is a segment from an interview with Brenda. Brenda is the teacher in this study and her views about school science and contemporary world of science and the role of school science is sought.

Excerpt 3: Of depth and complexity

R	Teacher interview 10th march 2006. Brenda, do you perceive school science to be different from science that is practiced as a scientist?
T	Science that is practiced by a scientist. ***Not just the content but also the process the skills that are involved. I think number 1 it has to be different because of the depth and the complexity.***
R	It will be different. But erm…
T	In school we try to ***maybe crystallize and make the more complex and complicated science scientific knowledge and simplify for students to understand it in an easier way.*** And then you try to ***exemplify the skills***, what are the skills. Let's talk about the attitudes first. ***The attitudes of a scientist that would help students if they want to go into research or any attitudes whether they are meticulous, persevering, all these traits and attitudes.*** And thirdly the skills. Whether they have certain skills. For example in school we will teach them how to handle different equipment. For example biology, we will try to teach them how to handle a microscope, micropipette. So we give them skills that help them handle equipment, or skills that help them conduct experiments, design experiments but definitely in a much simplified way than what scientists use. Erm erm not only lab based but also out in the field, research, ecological experiments. Yah.
R	In your view what do you think is the end of goal of school science?
T	The end goal of school science. I think increasingly ***I change my perspective. Maybe initially when I started off as a teacher,*** you think that it is just content knowledge that you need to teach your students, and of course the content knowledge surrounds the syllabus, whether they pass their O and A levels and get into a good JC or university. But increasingly through years because society has changed and trends has changed ***I think personally*** that it is important for students to be good at these interpreting data especially scientific data because of the explosion of science knowledge and data. And hence ***they must have the ability to read and understand analyze and sometimes make decisions as to what kind of stand or decision they want to make.*** And that therefore comes in together with social responsibility as a citizen of Singapore where you have a t times a choice or a stand to make. In certain critical decisions then you can make the democratic choice based on knowledge or understand and not based on just opinions by people. You should be able to discern. I think that is more important for me now than knowing how food is digested. Like you make the choice of whether this slimming pill works, whether it is working or whether you should support cloning or whether you should support because technology is moving so fast. The future students or young people ***should be able to make these decisions***.

Table 3: MCA according to Brenda

Category	Membership Categorisation Device	Category Bound Activity
Science as practiced by scientists	Practices of science	Not just content but also the process; the skills. (lines 3-4)
Science in school	Practices of science	To simplify more complex and complicated scientific knowledge for students to understand. (lines 8-9) Teaching students skills, attitudes and content. (lines 10-13)

Beginning teacher	Responsibility	Teach content knowledge to pass examinations. (lines 23-25)
An informed and reflective teacher	Responsibility	Helping students to interpret data (line 28) and making informed personal decisions. (line 40)

Brenda stated explicitly that she thought that school science is different from the contemporary science. She attributed the difference between school science and contemporary science to the activities which each is engaged in. Again, we notice the uniqueness of category bound activity that helps to define the two categories. For Brenda, science that is practiced by scientists involved both content (scientific knowledge) as well as skills. In schools, these scientific knowledge and skills are reshaped and transformed so that they can be made accessible to the students. Here, Brenda draws a parallel between knowledge acquisition of the individual and the knowledge construction in the history of science as seen in lines 29-31 where Brenda relates to the critical inquiry attitudes that students need to have to make informed choices of scientific information that is presented. (cf. Nussbaum, 1989)

When asked about the specific role of school science, Brenda revealed two categories from which different roles of school science can surface. Brenda spoke from the membership categorisation device of responsibility and how different categories of responsibility will result in different activities. When she reflected on her role as a beginning teacher, Brenda perceived the end goal of school science is to help students learn the content knowledge and to pass examinations. This identity as a beginning teacher defined the activity she engaged in and hence shaped the end goal. On the other hand, from an individual point of view now as an informed and reflective teacher, Brenda sees her responsibility as one who should help students learn how to interpret data so that they can make informed personal decisions in science. This end goal of school science is different for her as a beginning teacher and an informed and reflective teacher.

DISCUSSION

The analysis above shows that there are at least two different views about what school science is and how it is compared with the contemporary world of science. Kathy and Jona presented their views as science learners and they see school science to be a part of contemporary world of science – an elementary section of what contemporary work of science is. They see school science, progressing from primary to secondary school, as progression along a continuum. Brenda, taking on the identity of a teacher, expressed a more complex view that espoused the dilemma of the roles, goals, norms and expectations of school science and contemporary world of science. The reasoning given by each person for their categories appeared to be guided by the activities that they are engaged in the teaching and learning process. The descriptions are focused mainly on the act and the role of the teacher rather than on the ontological or epistemological comparison. There is little evidence to suggest that they question the origin of the scientific knowledge despite the explicit nature of the question asked. Regardless, the views provided by Brenda, Jona and Kathy are valuable for us in understanding their classroom practices, their views of science, the ways their views and how science is 'practiced' in class are intertwined and the similarities and differences between these practices and those of the contemporary world of science. Despite the lack of focus on the origin of scientific knowledge, the ideas expressed by Brenda, Jona and Kathy suggested that adopting the science learner as a scientist required fundamental examination of the relationship between school science and the contemporary world of science (Caravita and Hallden, 1994). The accounts illustrated above concur with the current debate on some foundational assumptions about science teaching (O'Neill & Polman, 2004; Bencze & Hodson, 1999). Both in the research literature and in the everyday discourse of teachers, the assumption that science teaching is of value because it allows scientific concepts, theories, and methods of problem solving to permeate from the world of science to the common people can be problematic. However, the idea of simply designing a science curriculum based on the knowledge and methods of science and hoping that students and teachers will be initiated into the world of science appears to be a highly romanticized one.

It is important to highlight that the reasoning and categories that are used by the teacher and the students are compared using the same membership categorisation device. Different membership categorisation device will yield different category bound activities. A person could be described by various categories, but at any one time, they probably would exhibit a predominant identity. What category one would put a person is dependent largely on the situation. However, regardless of what categories used, these categories would fall largely into different devices. In the discussion above, we exemplified the various categories which the learning of science may have and the resultant category bound activities to define each category. The learning of science can fall largely into primary school science, secondary school science and science as practiced by scientists.

In this paper, we surface some views and opinions which teachers and students may have about school science and the scientific enterprise as practiced by scientists. These views and ideas are dynamic and changes with time. Regardless, the existence of these thoughts provide enough reasons to convince teachers and science educators of the diversity of views about the nature and role of school science and the similarities which it shares with contemporary science. The boundaries between school science and contemporary science (we are hesitant and careful to label them as separate disciplines) are fuzzy and it is timely that science educators give some thoughts about how school science can be defined and what are some areas of contemporary science that can be borrowed in shaping the identity of school science. The ontological and epistemic issues in school science are worth exploring in the context of school science in different cultural variations because the different views and ideas that people hold in their heads will govern their actions. This invisible governance is what Sacks (1995) termed as *'internal systems of social control'*. This form of control is not imposed by laws or rules set by others outside the community but rather by people within the community. What this implies is that when people of the same view come together, they will abide by the social norms that are formed and these social norms will shape and reshape their behaviours. Perhaps, if the social norms of school science can be defined, clearer disciplinary markers to define school science as an independent discipline will be possible.

Science educators and scientists exist in different social spaces with different social norms. Blending these social norms, behaviours, practices, ideologies and goals will make it difficult to negotiate and understand the roles and practices of science educators. Clearly, the accounts which we present above illustrated the complexity of defining the social norms of the various categories of learning science. There is difficulty in uniting and defining the categories to account and renegotiate what is uniquely school science and what are aspects 'borrowed' from the contemporary whole of science. From the preliminary analysis of the interviews above, we have provided a case for exploring and understanding further how students' understandings of what school science is and classroom practices are intertwined with the contemporary world of science.

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