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Science as Inquiry: Partnership for Change in the 21st Century

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Abstract

Historically, science education reforms hold the promise to better science teaching and learning in classrooms. Calls for change in science classrooms includes a more from transmission mode of instruction to more discovery and inquiry forms; from simple laboratory experiments to incorporate more sophisticated forms of technology in school laboratories. Regardless of the change, it is important to recognize that science education change occurs within a complex network of interacting factors such as societal norms, teachers' personal beliefs about science and also students' expectations about school. In this position paper, I make a call for science education researchers to position their educational innovations and change as a form of partnership between the different parties involved in the change process so that true transformation can take place.

Keywords: scientific inquiry, science education reforms , 21st century skills

1. Introduction

Educational reforms often hold the promise to improve educational outcomes and greater accessibility to education. In recent times, different economies have actively transformed their science education in an attempt to reduce educational wastage and improve scientific literacy. A common characteristic of these reform efforts is the focus on how students and teachers interact with one another in the physical learning space of the classroom or through the virtual learning spaces online (Koschmann, Hall, & Miyake, 2001). In the recent International Conference of Science Education and Teachers 2014 (ISET) conference held in Phuket, Thailand, the theme for the conference was *Transforming Classrooms for the Next Generation Learners*. The word *Transformation* suggests a drastic or marked change. It is change that is easily observable and noticeable. For example, during metamorphosis of a butterfly, the pupa is changed into a beautiful butterfly. The butterfly bears little physical resemblance of the pupa. This drastic change is a characteristic of transformation. However, unlike metamorphosis which is an inherently programmed change that will occur with minimal pressure from the external environment, educational change usually occurs when provokedby external stimuli. Societal changes and expectations may signal a need for changes in education but these external stimuliare often insufficient to trigger transformation in our classrooms. Rather, for educational transformation to take place, educators must make a deliberate decision for change and take active steps towards making classrooms and school different and more progressive.

Once educators are convinced of the need for change, the next decision to make is to determine the kinds of changes that one can make so that the education change is meaningful and transformational in nature rather than superficial and reactive. The world in the 21st century appeared to be vastly different from the 20th century. With the rapid progress made in science and technology, it has redefined how people interact with each other. As we progressed through the 21st century, there is great emphasis on then need to focus on the development of 21st century skills for our learners. What exactly are 21st century skills and how are they different from the 20th century forms of learning that we are familiar with? What are the key differences between the demands made on learners in a 21st century classroom when compared with the 20th century classroom? There are multiple aspects to compare between the 20th century classroom (from the period Jan 1, 1901 to Dec 31, 2000) and the 21st century classroom (from the period of Jan 1, 2001 to Dec 31, 2100). Comparing aspects such as *ways of thinking, ways of working, tools for working, and skills for living in the world,* it is obvious that the skill sets required to excel in life in the 20th century is vastly different from the demands made in the 21st century (Bellanca& Brandt, 2010). Computers, robots and modern information technology form the dominant way of working and communication in the 21st century as compared with the typewriter and less powerful and sophisticated first generation computers in the 20th century. With more advanced technologies, societies are encouraging cross countries and cross cultural collaborations rather than local collaborations. With regard to the ways of thinking, the 20th century focused on rule setting and conforming to prescribed sets of standard operating procedures while the 21st century demands that the learners engage in creative problem solving and critical thinking. In a more connected and globalized 21st century, there is even more emphasis on global citizenship and social responsibility (The Glossary of Education Reform, 2014).

Cognizant of the demands of the 21st century, science educators around the world are also gearing up to ensure that science classrooms and laboratories of the 21st century can meet the demands made by the society. But what forms of changes can we expect? With rapid changes in the physical environment, the need to find a balance between sustainability of the solutions as well as handling the fast changing technological advancements proved to be challenging. The world has entered an era where knowledge of science and technology are very closely knitted in the everyday lives of every individual. Even more urgent in the 21st century is the need to ensure that our citizens are scientifically literate so that they can be informed consumers of science in their everyday lives. In order to be scientifically literate consumers of science, schools need to provide students with a science learning environment that is not just rich in science content that is current, but rather, they need to offer students with a space to inquiry about the science content that they encounter (OECD, 2006). Inquiry into the science materials and methods that the students are exposed to encourages collaborations and develop critical thinking and problem solving skills (NRC, 2000).

Educational transformation or change cannot take place in a vacuum since science teaching and learning are embedded in a complex network of interacting factors such as policy, people, and places (Honig, 2006). Making sense of all the factors and their interactions often proved to be challenging. As such, systematic and timely research is important. The notion of partnership for change came about because of the realization that transformation cannot take place unless we have in-depth knowledge and understanding of all parties involved in the change. Educational change is not unidirectional but rather a dialectical relationship between the teachers and the learners. While it is important to consider all parties involved in any researchon educational innovation, it is often challenging to examine all the different interacting parts of the network at the same time. As such, in this paper, I havefocused on two most important (and accessible) group in the network of change – the teachers and the students. In this position paper, I argue that educational transformation in science classrooms can only truly take place when there is a close partnership between all parties (figure 1) involved. Using some research was carried out previously in Singapore, I illustrate the need to develop a strong partnership in our attempts at transforming our classrooms. The research questions that guide the development of ideas in this paper are:

1. What are teachers' ideas about science as inquiry in science classrooms?
2. What are students' ideas about science based on their science classroom experiences?

2. Science Education in Singapore

Singapore has traditionally done well in international comparative studies such as TIMSS and PISA (OECD, 2010). As such, there is interest surrounding science education in this tiny island state in South East Asia In Singapore, the science inquiry efforts received a renewed emphasis in 2008 when it was identified as the central and guiding philosophy and pedagogy of science education reforms. With this change, science teachers and science education researchers in Singapore faced issues of differing understandings of inquiry (Kim, Tan, &Talaue, 2013). While research literature is rich in information about problems and issues with science inquiry globally, it is also widely recognized that education is context-based and has unique norms in different societies and cultures. Existing models of science inquiry gives little attention to learning by listening attentively, a characteristic trait of good science and also a feature that is typically associated with Asian science classrooms. In fact, science inquiry research typically focused on getting students to engage in asking questions and performing investigations to find out the answers (Minner, Levy, & Century) with little attention paid to the role of direct instruction by the teacher (Kirschner, Sweller, & Clark, 2006).

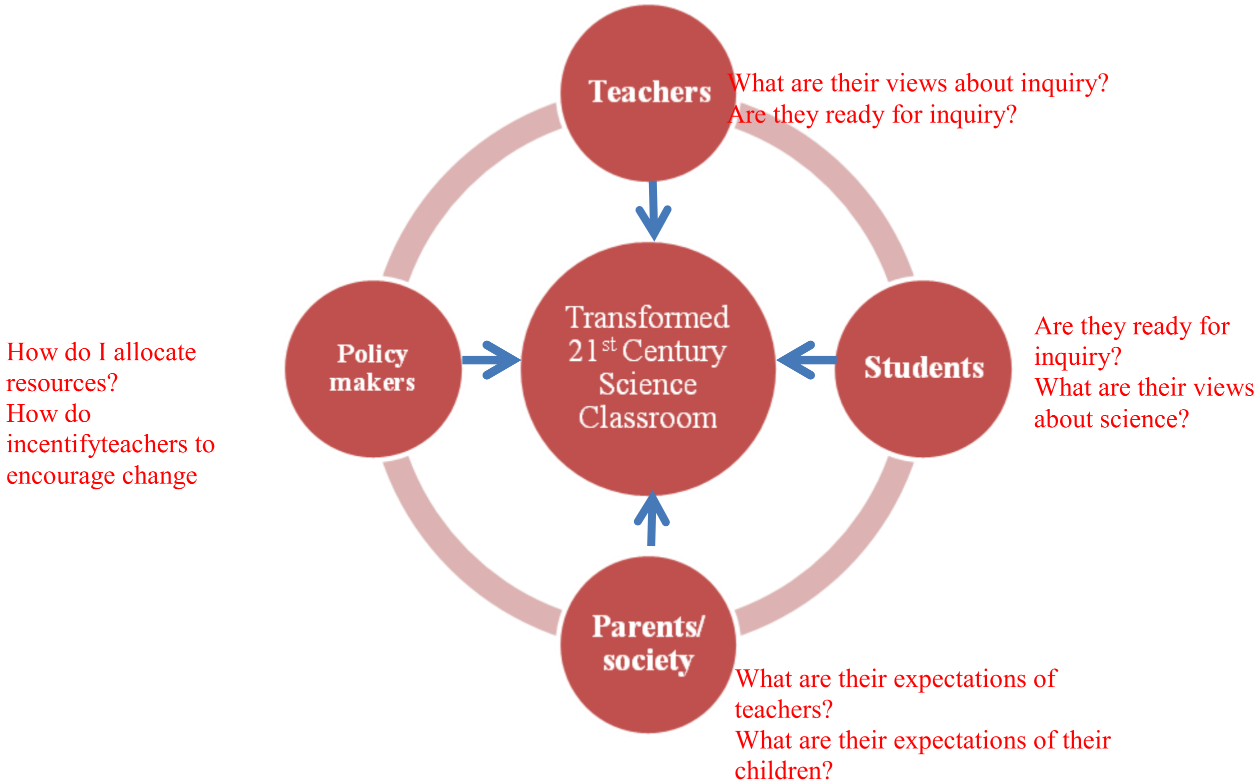

Figure 1. Stakeholders in partnership for change

Thus, it is critical to understand the perceptions and difficulties teachers in Singapore experience in order to develop effective classroom practices of inquiry-based teaching within the highly successful context whereby students sit and listen attentively to the teacher transmitting knowledge. Research into the various aspects (such as teachers' beliefs, ways to support teachers' professional development in using science as inquiry and suggesting possible frameworks to help teachers use science as inquiry confidently in the classrooms) of science inquiry classrooms and practices have been actively carried out in Singapore in the past three years (e.g., Kim, Tan, &Talaue, 2013; Lee, 2011; Poon, 2010; Poon, Lee, Tan, Lim, 2012; Tan, Wong, Tan, & Lee, 2009). Internationally, research in science inquiry has also delved into difficulties faced by teachers in implementation (Crawford, 2000; Kim & Tan, 2010) but little has been said about platforms for teachers and students to work collectively to overcome the hurdles presented by science inquiry in classrooms. I argue here for the need to privilege the position occupied by differences and contradictions in order to progress in our understanding of teachers' motivations to practice science inquiry. Currently, we still have limited understanding of teachers' and students' school science experiences within a routined setting. We posit the timely adoption of a more social view of inquiry by involving learners and teachers of science in co-constructing science inquiry by participating in dialogue about inquiry – experiencing, talking and listening to each other's experiences in the science classroom.

3. Research Findings

3.1 Teachers' Ideas about Science as Inquiry

Different aspects of inquiry science implementation in Singapore primary science classrooms have been given attention by several research initiatives in recent years. For instance, our past research delved into teachers' perception of inquiry science (Kim, Tan, &Talaue, 2013). In our sample of about 50 in-service teachers from one cluster of schools, we found three mental images that predominate their thinking about the inquiry approach: inquiry with knowledge focus, inquiry with teacher guidance, and inquiry with assessment conflict. In another case study of four teachers' adoption of inquiry science, it was found that the pedagogical framework employed in actual practice gave importance to students' cognitive and procedural readiness, iterative teaching for concept development with continuous monitoring of learning, and synthesizing science concepts at a terminal consolidation phase (Poon, Lee, Tan, & Lim, 2012). These studies definitely enrich our knowledge about local practices of primary science teaching but it remains to be seen if the images of inquiry science are held by a broad number of teachers and if there are other images that could account for the wide variety of teaching contexts in schools. Also, what has been neglected in previous research endeavors is a focus on students' disposition for, and their social interactions during, inquiry science teaching.

Teachers' ideas about science as inquiry will inevitably influence what they perceived as important in the science classroom (Crawford, 2007). Consequently, it also shapes the teaching that is practiced in the science classroom. In a study by Tan, Talaue, and Lim (2013), where 194 Singapore elementary science teachers responded to a survey crafted using the Theory of Planned Behaviour (Ajzen, 1985), they found that teachers who participated in the study generally have positive attitudes towards practicing science as inquiry. The teachers believed that science as inquiry can help to promote students' collaboration and deepen students' learning of science concepts. Further, the teachers in the study also experienced moderately positive social pressure to practice science as inquiry. Teachers try to meet expectations set by students, colleagues and then school administrators when it relates to making decisions about science as inquiry. Lastly, teachers indicated that they have confidence and perceived that they have some control over their practices of science as inquiry. They believe that if they practice science as inquiry, they will be able to motivate their students in science. These aspects of teachers' beliefs about science as inquiry are encouraging since this is usually the first step toward embracing the change process.

From these findings, it is evident that while teachers in Singapore try to integrate the ideas of science as inquiry into their practices, they have failed to transform their classrooms. They have tried to graft the changes required from science as inquiry into their existing practices to create new learning experiences. Unfortunately, most of the time, the classrooms and students' learning experiences still resembles very much of the 'old' practice. Teachers highlight assessment pressure (Kim, Tan, &Talaue, 2013), crowded curriculum and students expectations as hindrance to their attempts at practicing science as inquiry. This is not unusual because educational transformations are not easy to achieve despite the most sincere efforts by teachers in classrooms. Lefsein (2008) rightly highlighted that teachers often misinterpret or selectively adopt segments of educational innovations leading to poor fidelity to the original intended outcome of the reform. Often times, we see a mutated form of the educational innovation emerging. Seven years into the science curriculum change, we are still trying to make that transformation of our Singapore science classroom a reality. We have made some progress and we realize that there is a tremendous need develop a holistic and localized framework of inquiry science that helps teachers recognize their personal agency for change and enable them to work collaboratively and in partnership with their students in order to develop classroom learning environments that are productive and transformative.

3.2 Students' ideas about Science

Students interact and work in close partnership with teachers to make learning possible. As such, understanding students' experiences and expectations are important for educational transformation. Students' reports are valuable to helping us understand and evaluate our teaching since the students have had ample exposure to the science learning environment and their teacher's approach. Understanding how students come to learn science from their perspective is thus essential to, in the first place, exploring alternative configurations in classroom activities and social interactions that would support improved learning over time. After the change in science curriculum emphasis in 2008, in an attempt to understand how science as inquiry has shaped students' ideas about doing school science, Zhai, Jocz and Tan (2014) embarked on a study to determine elementary science students' ideas about doing school science. They found that grade four Singapore students view doing science in school as (1) doing hands-on investigations, (2) a social process of interacting with their peers, (3) a process of learning from their teachers, and (4) completing their workbook. These perceptions of doing science in school is likely to be shaped by their personal experiences as classroom observations revealed that students are often engaged in working with manipulatives in groups and subsequently filling out their workbooks as a record of their learning and discussion. Zhai et al. (2014) further queried the students to find out how their science learning experiences shaped their ideas about being a good science student and consequently a good qualified scientist. It was somewhat disturbing to realize that 94% of the students stated being well-behaved as the most expected role of a good science student. A similar trend is also observed for the expected role of a qualified scientist with 54% indicating that being well-behaved is expected. Qualities such as seeking understanding and applying knowledge were rated relatively lower. Seeking and applying knowledge are fundamental and crucial to the scientific enterprise but was not featured as important from the students' experiences of doing science in school. What this finding seem to suggest is that more needs to be done to transform science teaching and learning such that students are exposed to more authentic forms of science learning experiences so that they can develop more progressive ideas about science.

In yet another study, Jocz, Zhai, and Tan (2014) examined the factors that affect elementary school students' interest in school science. They found that gender was not a significant predictor of interest in school science. Activities that will develop greater interest in school science include — (1) engagement in peer discussion, and (2) connecting learning to real life situation. This study about interest in school science suggests that students enjoy the kinds of activities that scientists engage in — discussions and dialogues among peers and solving meaningful real world problems. Teachers can create more learning spaces for students to engage in more talk and interactions to solve more real world problems. This will be one positive step towards transforming the classroom from one that is teacher-front and transmissive to one that is student-directed. This change, however, can only take place if teachers and students develop a common understanding of the goals they want to achieve.

3.3 Partnership for Change – Elusive Possibility?

In the discussion above, I presented the issues teachers' faced when practicing science inquiry and also the experiences that students have with school science. The current state of interactions between teachers and students is a result of teachers juggling expectations from the national curriculum as well as the demands made by the assessment system. Students respond to this hybrid form of practice of science inquiry by developing traditional ideas about school science and how it should be practiced. Open dialogues between teachers and students about the demands of the curriculum and the expectations of students in science learning could help to develop a more realistic, progressive and meaningful learning experiences for both the teachers and students.

Co-generative dialogues (whereby small groups of students and their teacher gather to talk) provide a platform for both teachers and students to talk about their common experiences in the classroom. Ong and Tan (2014) found that through co-generative dialogues, teachers can better understand what the students take away with them during lessons and students were more willing to offer their ideas about what they have learnt and how they like to learn. For example, through a series of co-generative dialogues, we found that students remember interpersonal interactions that occurred in class more than the science subject matter when they worked in groups. Upon probing by teachers during the co-generative dialogues, we found that conflict resolution feature very highly when students work on investigative tasks in a group. With this knowledge, teachers can explain to the students the need to work meaningfully with others and also devise ways to allow students to acquire skills to communication and negotiate within groups. Teachers could allow more opportunities for group work so as to allow students to "practice" their skills at conflict resolution and negotiating with others within a group rather than to reduce the number of group investigations. This partnership between the teachers and students is developed through dialogue to develop a better understanding of each other. The partnership is also possible because (1) the teachers and students work towards a common goal of a more meaningful science learning environment, (2) the teachers are willing to develop students' agency in their own learning, and (3) the students are sufficiently able to use their agency in a responsible manner.

4. Conclusion

I began this position paper to argue for the need to develop understanding of teachers' ideas about science as inquiry and their motivation for practicing science as inquiry and also students' ideas about doing science in school. Knowledge such as teachers' and students' ideas are important to help us evaluate how educational change should proceed and should there be deviations from the original intentions, how corrective measures can be mapped out. Unless efforts are made to develop partnerships between the various parties (teachers, students, science education researcher, parents, school, and society) involved in education change, genuine change in our classrooms will be slow to come. The voices of teachers and students should not be ignored but rather should be taken more seriously in any educational transformation exercise. As cautioned by Lefstein (2008), teacher isolation, forced compliance and lack of knowledge of teachers and students motivation render educational change invalid.

Partnership for change is dependent on many different factors interacting at different levels. As discussed earlier, these factors include the readiness of teachers, teachers' perception of social pressure of their practices, assessment demands outlined in the curriculum, students' perception of what a good science learner ought to be and others. In this paper, I presented findings from earlier studies on teachers and students separately to argue that these two groups of stakeholders need to be brought together for conversations about expectations and concerns so that their closely knitted learning relationship can be made more meaningful. Science education researchers can play a part in facilitating these conversations. They can act as the neutral party in these conversations and bring in fresh insights to the shared issues and experiences that the teachers and students have. Willingness, and knowledge coupled with understanding of these various interacting factors enabling or hindering the practice of science inquiry will help to ensure that we truly transform our practices and classrooms for the 21st century.

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