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Exploring the potential of using stories about diverse scientists and reflective activities to enrich primary students' images of scientists and scientific work

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Abstract The purpose of this qualitative study was to explore the potential of using stories about diverse scientists to broaden primary students' images of scientists and scientific work. Stories featuring scientists from diverse socio-cultural backgrounds (i.e., physical ability, gender, ethnicity) were presented to 11 grade one students over a 15-week period. My analysis of pre-and post audio-taped interview transcripts, draw-a-scientist-tests (Chambers 1983), participant observations and student work suggest that the stories about scientists and follow-up reflective activities provided resources for students that helped them: (a) acquire images of scientists from less dominant socio-cultural backgrounds; (b) enrich their views of scientific work from predominantly hands-on/activity-oriented views to ones that includes cognitive and positive affective dimensions. One of the limitations of using stories as a tool to extend students' thinking about science is highlighted in a case study of a student who expresses resistance to some of the counter-stereotypic images presented in the stories. I also present two additional case studies that illustrate how shifts in student' views of the nature of scientific work can change their interest in future participation in scientific work.

Keywords Images of science · Images of scientists · Primary students · Stories about scientists

Interviewer:	Would you like to be a scientist?
Shruti:	No
Interviewer:	Why not?
Shruti:	I hate it
Interviewer:	Why do you hate it? [silence]
Interviewer:	What do you hate about being a scientist?
Shruti:	You have to build something

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The above excerpt is taken from an interview I conducted with a grade one student within the context of a study that explored the impact that stories about diverse scientists could have on students' notions of who can be a scientist and the nature of scientific work. The emphatically negative nature of Shruti's (a pseudonym) response was startling and heartbreaking; how could a student at the young age of 6, express such disinterest for the idea of being a scientist? Shruti's response to the question of what she hates about being a scientist reveals a view of scientific work or school science work that *necessarily* involves "build[ing] something". Not only does this view misrepresent the nature of scientific work but it is also evident that it constrains Shruti's ability to perceive science as an endeavor within which she can envision herself as an active participant. Researchers recognize students' views of the nature of scientific work as an important component of their scientific literacy and this excerpt highlights the impact these views can have on student interest in science.

While there are numerous studies that examine the role of practices/tools that extend students' images of scientists and scientific work, few of these target elementary students and fewer still focus on primary students (i.e., kindergarten to grade 3). In recognition of the potential role played by stories about scientists in shaping particular discourses around science and on the large body of literature on the central role of stories in the learning of young children (Wells 1986), stories about scientists from diverse backgrounds depicting diverse scientists at work were presented to grade one students. This study builds on previous studies that document and elucidate how young children develop understandings of themselves in relation to science, including, for example, the work of Eli Tucker-Raymond, Maria Varelas, Christine Pappas, Allu Korzh and Ashley Wentland (2007).

The goal of this study was to explore the potential of using these stories and follow-up reflective activities to help students like Shruti appreciate that people from diverse backgrounds can be scientists and that scientific work involves a rich variety of topics, methods and takes place in a variety of environments. The specific research question that guided my study was: How do stories about scientists from diverse socio-cultural backgrounds influence grade one students' images of:

a. scientists (i.e., characteristics such as gender, physical dis/ability, ethnicity and intelligence)?
b. the nature and purpose of scientists' work?

In this paper, I present data that suggest that these stories helped students acquire images of scientists from less dominant socio-cultural backgrounds and enriched their views of scientific work, from predominantly hands-on/activity-oriented views, to ones that include cognitive and positive affective dimensions. I highlight one of the limitations of using stories as a tool to extend students' thinking about science in a case study of a student who expresses resistance to some of the counter-stereotypic images featured in the stories. I also present two additional case studies that illustrate how shifts in student' views of the nature of scientific work can change their interest in future participation in scientific work. Elsewhere, I report on the impact these stories had on students' views of the social nature of scientific work (Sharkawy 2009).

Students' stereotypic images of scientists and scientific work

Since Margaret Mead and Rhoda Metraux's (1957) seminal study on secondary students' images of scientists and then David Chambers' (1983) study with elementary students, numerous studies (conducted within Western industrialized nations) have continued to suggest that students, from kindergarten to the senior level, hold inauthentic and unfavorable images of scientists and scientific work (e.g., Barman 1997). For several decades, students have persisted in depicting scientists as old, white eccentric males of extraordinary intelligence. Such narrow images of scientists exclude many groups of people including, for example, females, wheelchair-bound students or those with other physical challenges, students from non-Caucasian backgrounds and students who do not consider themselves of superior intelligence. Studies have also demonstrated that students hold inaccurate views of scientific work, both in relation to the kind of work they think scientists engage in and the environments in which they believe scientists work. Most students, for example, depict scientists involved in chemistry or technology-related work and working indoors, commonly in the laboratory (e.g., Flick 1990).

Stereotypes are characteristics that are perceived to be associated with particular groups or categories of people (Schneider 2004). Although social psychologists recognize that stereotypes develop, partly in response to individuals' need to simplify the social world through social categorization and generalizations, they also acknowledge the important role that culture—a social group's beliefs, knowledge, norms and ideologies—plays in shaping and reproducing stereotypes. The extensive literature on students' stereotypic images of scientists, for example, suggests that they are generated and sustained through a wide range of sociocultural agents including, schools, families, science centers, museums and visual and print media (e.g., magazines, television, books, cartoons). While these cultural agents typically circulate images of scientists that consistently encourage children to associate the social category "scientists" with the male gender, a Caucasian ethnicity, able-bodiedness, superior intelligence and so on, the local experiences and cultural practices and values students experience can also influence their image(s) of scientists.

It is, therefore, not surprising that despite the overwhelmingly prevalent stereotypic images of scientists documented by Mead and Metraux (1957), some studies have revealed differences in the way children from different parts of the world perceive scientists. For example, Rebecca Monhardt (2003) found grade 4–6 Navajo students depicted scientists as females more readily than in other studies and most students depicted scientists working outdoors—in a tent or under the sky, rather than indoors in a laboratory. Similarly, as part of a large-scale international study aimed at ascertaining children's images of science and scientists, Svein Sjoberg (2000) found that children from less industrialized countries have a much more positive image of the culture of science than most children in the West and viewed scientists as "servants and heroes of society"—involved in ameliorating the suffering of the poor and underprivileged, and improving people's standard of living. In contrast, he found few children in industrialized countries perceive scientists as kind, human and helpful.

One of the widely acknowledged characteristics of stereotypes is that they are difficult to change once they are established. This resistance may be due to the self-perpetuating nature of prior beliefs and to the fact that, in addition to making associations between various characteristics and a social category, people often develop theories about why these characteristics are associated or more strongly associated with different groups. One of the models used to describe how stereotypes may change in response to disconfirming information is referred to as *subtyping* which assumes that when individuals encounter stereotype disconfirming evidence, they will view these cases as separate subcategories. While this may allow a person to acknowledge the disconfirming evidence while maintaining the previously established stereotype, some researchers argue that continual subtyping should, over time, effectively lead to the dissolution of a stereotype as a person begins to acknowledge the diversity of a group. This view of stereotypes may explain how, as Joan Solomon, Jon Duveen and Linda Scott (1994) assert, multiple and contradictory images of science and scientists can co-exist in the mind of students. For example, in their study, Solomon et al. found that their intermediate level student participants expressed several images of scientists including scientists as vivisectionist, technologist, teacher, pupil, entrepreneur and a 'cartoonish' image of a scientist who conducts mindless experiments. They used the notion of a "library" or "kaleidoscope" of images to characterize the multiplicity of their participants' images. Similarly, I embarked on this study with the hope that the stories presented to students would not necessarily 'replace' their views of science and scientists, but would enrich their existing 'library' of images.

Stories about scientists

In addition to their ability to engage the emotional sensibilities of readers and listeners, stories play a significant role in the construction, transmission and transformation of cultures (Witherell and Noddings 1991). They do this by explicitly and/or implicitly making assertions about various aspects of the world. As Catherine Milne (1998) notes, stories that showcase the work or accomplishment(s) of scientists help shape school science discourses by advancing particular notions—on explicit and implicit levels—about scientists and the nature of science.

Milne (1998) identified four types of science stories which promote different views of science: the heroic science story which presents scientists as heroes who independently make important contributions to science; the discovery science story, which features the development of scientific knowledge as having occurred as a result of an accident; declarative science stories, which present scientific knowledge or processes as solely relying on observation that is accessible to all; and politically correct stories which explore interactions between science and society and aim to fairly represent the contributions of people from different cultures. Thus, depending on the messages conveyed about science, stories can either promote an understanding of the diverse nature of scientific work and the people who do science or they can misrepresent various aspects of the nature of science.

Building on the work of Milne (1998), Zoubeida Dagher and Danielle Ford (2005) analyzed twelve biographies of scientists intended for primary and middle school children with the aim of identifying possible biases related to the characteristics of scientists and the nature of science. They used three questions based on the work of Rosalind Driver, John Leach, Robin Millar and Phil Scott (1996) to analyze the biographies. The first question focused on how the scientist in the biography was described (e.g., personal characteristics, hobbies, school experiences and formative experiences that shaped the scientist's work); the second question explored the nature and process of scientific knowledge as it was presented in the biography of scientist; and the third question centred on images of the social processes conveyed. Dagher and Ford's analysis suggest several possible distortions or biases that could be promoted by biographies of scientists written for children, including: portraying scientists as heroes destined for science; overemphasizing observation and experimentation; and not including the purposes, methods and social processes of science.

The stories about scientists presented to students in this study are examples of what Milne refers to as *politically correct stories,* as one of the primary objectives of the study was to promote the understanding that people from diverse socio-cultural backgrounds can be scientists. Hence, stories about scientists who represent groups of people traditionally marginalized from science were purposefully chosen (e.g., wheelchair-bound, blind, females, Native American, African American). And in contrast to the biographies of scientists analyzed in Dagher and Ford's (2005) study, the stories about scientists presented in this study were strategically used to communicate the following notions about science: the importance of the social dimension in scientific knowledge development; the purposes of science (i.e., describing and explaining natural phenomena); and the importance of asking questions and constructing theories in addition to observing and collecting empirical data. The scientists featured in the stories presented to students in the study included: Kathleen Dudzinski, Jane Goodall, Stephen Hawking, Mae Jemison, Rachel Carson, George Washington Carver, Frank Begay, Geerat Vermeij as well as Khalil and Judy, two fictional scientists. A brief summary of each story is provided in Appendix 1.

Mediation in the storyreading/telling

This study is informed by sociocultural theory and recognizes the important role mediation plays in children's learning (Kozulin 2003). There are two categories of mediation: (1) human mediation, including various forms of adult/more experienced peer involvement that lead to children's learning; and (2) symbolic mediation, which involves interactions with symbolic mediators such as signs, formulae, graphic organizers and texts. While it was anticipated that the symbols embedded in the stories (i.e., visuals and text) would play an important role in enriching students' views, the need for human mediation (in the form of teacher scaffolding) was also expected. Examples of human mediation strategies that were used to assist students in using the stories as a resource to extend their images of scientists and their work included: recruitment (e.g., capturing students interest at the beginning of the story through the use of a prop or question); direction maintenance (e.g., focusing students' attention on notions related to the nature of science/characteristics of the scientists when students focused on other aspects of the story); marking critical features (e.g., pointing to relevant images in storybooks); and frustration control (e.g., selecting only parts of the story text; paraphrasing and summarizing cognitively demanding/lengthy text) (Wood, Bruner and Ross 1976). Teacher scaffolding was also anticipated in guiding students through reflective follow-up activities at the conclusion of the story presentations (e.g., completing large-group chart to highlight relationship between scientists' questions, methods, location of work); all follow-up activities are described in detail in the *Presentation of stories* section below.

Storyreading/telling

This five-month study took place in a school located in a low socio-economic, multi-ethnic urban community in Ontario. At the time of the research, the school was working in collaboration with an international literacy organization on integrating storytelling into various aspects of the curriculum to increase student and family literacy. Thus, the integration of stories about scientists supported the goals of this school-wide initiative.

The participants of the study included 4 male and 7 female grade one students (6–7 years old) and their classroom teacher. All students who participated in the study represented visible minorities and were from diverse ethnic backgrounds: Sri Lankan, Chinese, Filipino and East Indian. It is important to note that all names of students included in this paper are pseudonyms.

The role of the classroom teacher and researcher (author of the study)

Although I located the stories and related resources, the classroom teacher provided input regarding the choice and/or presentation details of the stories and follow-up activities. While I told the stories and led follow-up discussions, the classroom teacher often freely jumped in and contributed comments and/or questions. Often, both the teacher and myself worked with students during the follow-up activities, circulating around the room, asking and responding to student questions.

Presentation of stories

I presented the stories and activities over thirteen 40–50 min lessons. My visits to the classroom often took place during the first morning period. The presentation of the stories involved three parts: (1) introduction; (2) storyreading/telling; and (3) follow-up activities. Both the storyreading/telling and large-group follow-up activities took place on the carpet at the front of the room where students typically sat during story-time. Following the large-group discussions, students were typically invited to go to their tables to complete their independent follow-ups (often entailing journal-writing). Examples of each of the three 'components' of the lessons are presented below.

Introducing the stories

Introductions to the stories usually took approximately 10 min. To invite students to articulate some of their ideas about scientists and science, the presentations of stories were typically preceded by questions. A 'prop' to stimulate students' interest and to help focus students' attention sometimes accompanied questions. The questions were also used to focus their attention on a particular aspect of the story (i.e., the personal characteristics of scientists, the nature and/or purpose of their work, where they work).

Stories were also sometimes introduced using a non-fiction book on the subject matter studied by the scientist. These books were used to help students make the link between the knowledge we currently have about the natural world and the work of scientists. After reading a few lines from the book, students would be asked to consider where the ideas expressed in the book came from. The first time I did this, before the story and video about Jane Goodall, the response from students included ideas like: "books, computers (http://www.janegoodall.org/chimpanzees), and school"—as well, many students were not able to articulate any view. However, later in the study when I presented the story of George Washington Carver, students' responses to this activity revealed a more broadened view of the relationship between existing ideas about the natural world found in books and the work of scientists. In addition to the view that books and computers were helpful, students' views at the end of the study about where the ideas about plants in a plant book come from included empirically based activities such as "looking at them carefully and writing down what they see", as well as "asking someone about them", and mental processes such as "thinking about why they grow" and "writing stories about them".

Many of the stories featured scientists who drew on current knowledge (e.g., in books and the Internet) to learn as much as they could about their topic but could not find answers to their questions from these sources alone. Instead, the scientists were featured engaged in such activities as asking questions, making observations and at times making predictions and theorizing (as in the case of Khalil and Judy, who each made a prediction about whether or not a seed from a desert plant can grow in sand and then tried to "explain" the result of their experiment).

Storyreading/telling

The storyreadings/tellings usually lasted approximately 15–20 min. Picture books, and videotapes in the case of Jane Goodall and Stephen Hawking, guided the storytelling/reading. Supplementary books and pictures of the aspect of nature studied by the scientists were sometimes presented alongside the stories about scientists (e.g., books on planets, animals). The stories were presented using a combination of reading (from picture or biographical books) and storytelling. For instance, when the text included in the storybook was too dense or linguistically advanced, I would stop reading and either omit segments (when they were deemed too detailed or not very relevant to the goal of the lesson) or paraphrase the text to reduce its cognitive and linguistic demands. During the stories, students were invited to share comments or ask questions. From time to time, I would stop the story in order to ask questions or highlight points to focus students' attention on characteristics of the scientists and aspects of their work.

Large-group follow-up activities

Following each story, there was a large-group follow-up discussion and an independent/small group follow-up activity. The large-group discussion often took place immediately after the story and often took approximately 10 min. However, when the story was long, the independent activities were introduced immediately after the story to give students a break and enable them to work independently at their tables, subsequently reconvening to the carpet before the lesson was over for the large-group discussion. The purpose of the large-group reflective components of the story presentations was to (a) focus students' attention and promote reflection on various aspects of the scientists (their personal characteristics) and their work (the nature, purpose and location of their work, etc.); and (b) assist students in appreciating the *relationship* between various aspects of the work of scientists (e.g., a scientist's particular interest is linked to the questions they ask; the questions they ask are linked to what they do, which in turn is linked to where they work).

A common follow-up activity involved completing, as a group, a table drawn out on chart paper to help students recognize the relationship between various aspects of the scientists featured in the stories and their work (see Appendix 2). Another large-group follow-up activity (used with the stories about George Washington Carver and Khalil and Judy) consisted of helping students complete a "thinking bubble" worksheet to encourage them to focus on the questions scientists ask, their predictions and their explanations for the results. This activity was useful in that it readily elicited from students their theories or hypothesis about the experiment worked on by the scientists. Additional large-group and guided follow-up activities included pair or small group storytelling as well as the presentation of stories to other classes within the school.

Independent follow-up activities

In addition to the group follow-up discussions, students were often invited to write/draw a more open-ended personal response in their journals. The purpose of the independent follow-up activities was to personalize the stories by (a) giving students an 'open space' to reflect on what they learned or found interesting about the story and (b) encouraging students to make connections between themselves and the lives and work of the scientist featured in the stories.

Ascertaining students' views of scientists and scientific work

Several sources of data were collected to ascertain students' views of scientists and scientific work: in class observations, semi-structured interviews with students, Draw-a-Scientist-Tests (DAST) (Chambers 1983) and student work that emerged during the course of the study (e.g., pictures, journal entries).

My in-class observations included noting students' comments and questions related to their views of scientists and science, as well as students' engagement in the story activities, their interpretation of the stories and the discourses they drew on as they interpreted stories about scientists. Story discussions were not audio-taped because consent was not obtained for all students. Whenever possible, however, I recorded student participant comments and questions on chart paper during our class discussion.

I conducted individual interviews at the beginning and end of the study. Interviews took place during class time and were approximately 10–15 min long. The purpose of the interview questions was to identify how students described scientists and their work (what they did, where they worked, etc.).

Administering the DAST involved the following procedure: students were given a 8½ × 11 sheet of white paper and asked to draw scientists at work. The classroom teacher and myself walked around as students completed their drawings and asked them to tell us about their picture. Some students required more direct probing and were asked to describe what the scientist(s) in their drawing was doing. To reduce the demands of writing and to encourage students to provide as much verbal detail as they could about their drawings, the classroom teacher and myself recorded what they said verbatim onto their sheet.

Students were asked to tell a story about scientists before and after the study. Some of the children's stories were audio-taped and transcribed and others were typed by me into a computer as students told their stories. When necessary, students were asked questions for the purpose of clarification and/or to encourage them to elaborate or provide more detail. Students were told that the purpose of the storytelling task was to hear their ideas about scientists.

Student interviews, stories about scientists and draw-a-scientist-tests were analyzed using a coding process which began with the identification of important categories highlighted by the research on students' images of science and scientists (Miles and Huberman 1994). These categories included characteristics of scientists (e.g., gender, ethnicity, cognitive ability, physical ability); and the nature, purpose and location of scientific work. The affective dimension of scientific work was not a category highlighted at the beginning of the study but was identified in the post-study data using an inductive coding process (Strauss and Corbin 1998).

Changes in students' views

Part one: student's views of scientists

Shifts in students' views are presented in two sections. The focus of the first section is on changes in students' images of the physical ability/disability, ethnicity, gender, and intelligence of scientists, followed by a case study which features a student who expressed resistance to some of the counter-stereotypic images of scientists featured in the stories. In the second section, I outline general shifts in students' views of the nature and purpose of scientific work and then present two case studies that illustrate how shifts in student' views of the nature of scientific work can change their interest in future participation in scientific work.

Students' views of physically challenged scientists

Students' views of only two physical disabilities were considered in this study—blindness and being wheelchair-bound. To gain access to students' views of blind and wheelchair-bound people as scientists before sharing the stories of Stephen Hawking and Geerat Vermeij, two photographs of men (one in a wheelchair and one with a walking stick) were shown to students in small groups. Students were asked to indicate if they thought the people in the photographs could be scientists. The response was unanimous; all students said no. Some of the reasons provided by the students for the man in the wheelchair included: "Maybe in disguise—he's hiding a scientist underneath" and "No because scientists don't sit on those chairs". In response to the photo of the blind man, some of the students' comments were: "No, because he can't see where he's going" and "No because he can make an accident and spill his work".

At the end of the study, all students agreed that wheelchair-bound people can be scientists. However, in addition to their explicit agreement when shown the photos and asked directly about their views, students revealed they had acquired an image of a wheelchair-bound scientist by making spontaneous references to Stephen Hawking in their work or interview. For example, in her post-interview, when asked about the **"**kind of people who could be scientists", Fazeela explains: "…Some scientists are in wheelchairs; some play sports even when they're taking the day off". Similary, Fig. 1 is an example of a male student's post-DAST of Stephen Hawking. Faruq describes, in his own words, his picture: "He's thinking why do black holes appear in space. That's Stephen Hawking—he's thinking about all the planets." However, while all students, by the end of the study, expressed the belief that people requiring wheelchairs could be scientists, only 7 of the 11 students expressed the same view for blind people.

Students' views of the gender of scientists

Analysis of students' pre-and post-DASTs and stories about scientists revealed some modest but notable changes in students' views with respect to the gender of scientists. Males consistently depicted a scientist that matched their gender, both at the beginning and end of the study. With the exception of one male student who drew a picture of both a male and a female scientist at the beginning of the study, no other male student, at any other time, drew a picture of a female scientist. This finding is consistent with previous research that has documented male students' strong tendency (both before and after interventions) to draw pictures of male scientists (e.g., Finson 2002). However, by the end of the study, 3 out of the 4 male students gave names of female scientists featured as part of the study, suggesting that, although male students drew and told stories about male scientists, they nonetheless, by the end of the study, possessed an image of a female scientist.

At the beginning of the study, female students' representations of the gender of scientists were less consistent across data sources but revealed clear signs of gender-role stereotyping of scientists. In addition to depicting scientists as males, for example, some of the female

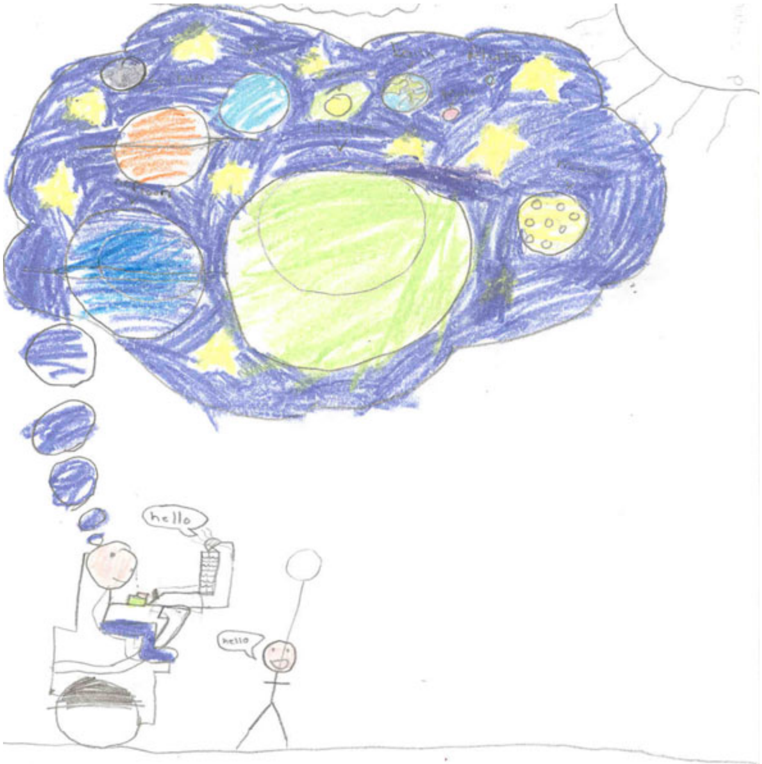


Fig. 1 Faruq's post-DAST. "He's thinking why do black holes appear in space. That's Stephen Hawking—he's thinking about all the planets."

students showed evidence of bias with respect to the work carried out by female as compared to male scientists. For instance, one of the female students (Renu) drew a female in her pre-DAST but described her female "scientist" as "finding some rocks to give to the scientist because *he* needs them"—clearly positioning her female scientist in a helping or subordinate role to a male scientist. By the end of the study female students depicted scientists as females more consistently across all data sources (e.g., pictures and stories), suggesting a reduction in the female students' gender-stereotyping of scientists. While this reduced portrayal of male scientists does not necessarily mean that the female participants developed more egalitarian views of the role of male and female scientists in science, it does suggest that the girls in the study developed more female images of scientists by the conclusion of the study. One reason that could account for this is that, while students were encouraged, through the presentation of stories about various female scientists as Mae Jemison, Rachel Carson and Kathleen Dudzinski, to appreciate that females can be scientists, they were not led to reflect on how the work of these scientists were not "secondary" to the work of male scientists (as some students' pre-study data suggested).

Students' views of the ethnicity of scientists

As with their gender-image of scientists, female students, at the beginning of the study, showed a greater tendency to depict scientists as different from themselves with respect to their ethnicity. For example, 75% of the males depicted a scientist the same colour as themselves, compared to 57% of females. This finding is consistent with research that found girls produced more gender and racially biased pictures of scientists than boys (Finson 2002). At the end of the study, the number of students who drew a picture of a scientist of the same ethnicity as themselves decreased. Specifically, 1 male student who drew pictures of scientists of colour at the beginning of the study drew Stephen Hawking, a white scientist, at the end of the study. Similarly, 2 female students who drew scientists of the same ethnicity as themselves at the beginning of the study chose to draw pictures of Rachel Carson—a Caucasian scientist featured in the stories presented in the study.

I do not, however, interpret this shift as an indication that these students *deleted* their image of a scientist of colour and replaced it with an image of a Caucasian scientist. Rather, a more likely interpretation is that these students, by the end of the study, have expanded their repertoire of scientists to include *specific* examples of female scientists. It is also important to note here that when students were asked to choose a story or scientist they found most interesting, the rationale they gave for their choice almost consistently related to their interest in the topic the scientist studied. Hence, it also cannot be assumed that the students who chose to draw a Caucasian rather than a Black scientist from the stories did so because they found him/her more convincing or plausible as a scientist; their choice could have been more influenced by their interest in the subject matter studied by the scientist rather than the plausibility of the scientist presented.

Students' views of scientists' "intelligence"

At the beginning of the study students' pre-interviews and large group brainstorming sessions yielded insights into students' perception of the intelligence of scientists. A variety of probes were used in the interview session to encourage students to articulate their views. For example, students were asked to describe the kind of people who could do science and how scientists are different from other people. Additionally, during the large group brainstorming sessions, students were invited to share any thoughts, words, feelings or anything that came to their minds when they thought of the word "scientists". When students added the word "smart" to the web, they were encouraged to describe what they meant by "smart", or in what way scientists were smart or smarter than other people. This brainstorming session was useful in that it highlighted some of the notions students associate with the special 'intelligence' of scientists. Students' responses, together with their pre-interview comments, suggest, broadly speaking, four 'dimensions' students consider a part of, or related to the superior or special intelligence of scientists:

- Knowledge: "they know everything"
- Skill: "they know how to make everything"
- Infallibility: "they don't make mistakes"
- Discovery/Novelty: "they can discover nature/stuff"

Scientists were considered smart because they knew (or learned) *everything* or *lots of things*; they could make *everything or lots of things*; they were able to find nature that no one else was able to find; and they didn't make mistakes. They were, therefore, seen as people who knew everything, made everything and discovered the world—and did so without mistakes. It is interesting to note that when students described scientists making mistakes, their conceptualization of mistake was equivalent to the notion of an accident. As one student described it, "Sometimes they [scientists] do [make mistakes] because I have a tape that's called, *Spiders and Scientists*. He [the scientist] made a mistake …he put green by accident. Then everything turned green in the house." (Sklya, post-interview). Skyla's example of the kind of mistake scientists could make (e.g., adding the wrong chemical) could be contrasted with the more cognitive-related "mistakes" students conceptualized as part of what it meant for them as students to make mistakes: "doing your homework wrong" or "doing messy printing".

It is important to note that these views about scientists were gathered in a large group context and, of course, should not be interpreted to mean that all students possessed these views or to the same extent. Since some of the students did not contribute during this session and did not respond to the pre-interview probes, it was difficult to ascertain their views on this characteristic of scientists at the beginning of the study. However, for two students, the notion that scientists are smart seemed to occupy a central place in their thinking or network of ideas about 'scientists'. They spontaneously described scientists as smart during the pre-interview. For example, when asked at the beginning of the interview who scientists are, Raja explains:

> A scientist usually start with making stuff and then start with cleaning and going with cameras to see what happens and discovers more things and very smart. And science usually like to *do very smart stuff* so they will get better things to do. And that's all.

Later in the pre-interview, when invited to consider what scientists do, Raja clearly places emphasis on their ability to do things "correctly" and "good":

Interviewer:	What kind of things do they do?
Student:	They like to build rocket ship and they have a camera—They see out of space and they can do other things with the rocket ships and they can also see the people…
Interviewer:	What other kinds of things do they do?
Student:	They also do homework *correctly*. They also do painting *correctly*. And they do *everything good* because they don't waste time talking

Later in the pre-interview, when asked what kind of people can do science, he remarks: "…anybody, only if they're *smart* like scientists". Similarly, in her pre-interview, Skyla begins her description of scientists by referring to the fact that they are "smart":

Interviewer:	What are scientists?
Student:	People
Interviewer:	What kind of people?
Student:	Smart people

At the end of the study I encouraged students during the post-interview to reconsider two of the ideas related to scientists being smart produced by our initial brainstorming session: (1) if scientists knew everything; and (2) if they made mistakes. Nine of the eleven students at the end of the study expressed the view that scientists did not know everything. Other students expressed more mixed views. For example, at the end of the study, Kumar concedes that scientists don't know everything but continues to express an inflated notion of the intelligence of scientists. He does not think they make mistakes because he views them as smarter than 'normal people':

Interviewer:	Do scientists know everything?
Student:	No
Interviewer:	Do they ever make mistakes?
Student:	No

Interviewer: Never?
Student: Never!
Interviewer: How do they do that?
Student: I don't know
Interviewer: Why do you think they never make mistakes?
Student: Because they're smart
Interviewer: Smarter than most people?
Student: Ya
Interviewer: Do they ever change their ideas about things?
Student: Ya
Interviewer: What would make them change their ideas?
Student: They think of something else

Similarly, Raja's post-interview hints at a 'partial' shift or consideration of the capabilities of scientists. While in our group discussion near the beginning of the study he described scientists as "knowing everything", here, this notion is less clear. He begins by asserting that scientists don't know everything but then seems to try to explain that, while they may know everything, they have to apply effort to find the evidence to show what they know.

Interviewer: Do scientists know everything?
Raja: No…because scientists- they know but they can't prove it…So, if they get in an argument they can tell—like, that's not happens and she's like, "Prove it"—and that's why the scientists don't know how to prove that thing—because they can't, so then they go out and try to find the proving

Case study 1: resisting the images of counter-stereotypic images of scientists

Raja is a very outspoken six-year-old boy, described by his teacher as "above average" in ability and confidence in science. Like Skyla, he had appropriated a lot of science vocabulary (cells, molecules, experiment) which suggests he had significant exposure to science outside school.

However, unlike Skyla and Shruti, Raja's interest in becoming a scientist did not shift throughout the course of the study. Both at the beginning and the end of the study he expressed an interest and confidence in science but a desire to pursue cartoon drawing. Again, unlike Skyla and Shruti, Raja expressed resistance to two scientists presented in the study—Mae Jemison and Rachel Carson. In the following excerpt of my post-interview with him he describes Mae as ugly—which was how he described what she was wearing during the presentation of the story:

Interviewer: Raja, what did you learn from the story about Mae? Was that an interesting story for you?
Raja: N-O- [spells it out]. No…She looked ugly and not so good. And she didn't actually look like a scientist to me
Interviewer: Why?
Raja: Because she looks like—she wears a helmet and she's going out. I don't think so—she's a scientist
Interviewer: No?

Raja: Yes, because … nobody's seen an African be a scientist and go outer space so I think she's not a scientist. She's just somebody going out of space, taking a picture and going down

Clearly, the image of Mae wearing an astronaut uniform and going up into outer space in the storybook used in class did not convince Raja that Mae was a scientist. He does not interpret Mae's work of going to outer space and taking pictures as evidence of her identity as a scientist. Instead, he describes her as "just somebody going out of space, taking a picture and going down". We can interpret Raja's reluctance to acknowledge Mae as a scientist as well as his remark that she "looked ugly and not so good" as suggestive of an appropriated racist attitude. Although one gets the sense that Raja is struggling at the beginning of the interview to identify exactly why Mae didn't look like a scientist to him, his comment that "nobody's seen an African be a scientist and go outer space" reveals his lack of exposure to Black scientists and the lack of representations of Black scientists prevalent in the media, in general.

As in his response to Mae, Raja refuses to accept that Rachel is a scientist:

Interviewer: What did Rachel study? Was Rachel a scientist?
Raja: Rachel….No!
Interviewer: No?
Raja: N-O- [spells it out] No
Interviewer: Why?
Raja: Because she didn't look much like a scientist. Because she only wrote things on a book and she only put it in there. She could actually do this book and write things on paper and put it in the newspaper to get more attention because newspaper goes all around the world. [?] Putting it in a book sometimes magazines, sometimes people can't find that- sometimes people can't find the book but in newspapers, always you can find this and that…
Interviewer: So, you didn't think Rachel was a scientist either?
Raja: No

When pressed to consider if Rachel could become a scientist if she modified her publishing venue, he turns to another aspect of her work that he finds unconvincing—her focus on only a few aspects of nature. He emphatically asserts that scientists study "lots of things" and in the following excerpt suggests his notion of the scope of what scientists study when he claims that they study "the whole world" or "everything":

Interviewer: Do you think she could become a scientist?
Raja: No
Interviewer: Why?
Raja: Because scientists usually think- put their things in a newspaper but she didn't—she put in a book
Interviewer: Okay, if she decided to put it in the newspaper, would she then be a scientist?
Raja: Scientists do lot more things
Interviewer: Yes or no?
Raja: No
Interviewer: What do they do?
Raja: But scientists usually study lot of things. They don't study one thing at a time. They study ten things or three things at a time. Because they want to

	show—they have to do these wonder in one day—they think and they do-they have to do one—they have to do more—they have to do two things—they have to do three things—they have to do four things
Interviewer:	Like what kind of things?
Raja:	Like anything … anything they don't know…

Raja emphasizes here his view of the intensity of scientists' work:

Interviewer:	How did you know that scientists do ten things at a time? They have to study ten things at a time?
Raja:	… They have to have hundred things in one day. They have to do—because when you're going to be a scientist …there's going to be a test and for the test, you have to do it one day… There's going to be ten or four things to study but if you do one thing, you're going to fail because you only learned one thing. If you do ten, you'll get a better hand. So a scientists now, usually, they do ten things at a time…

While Raja focuses on Mae's physical appearance and his lack of exposure to African scientists as rationales for why Mae didn't look like a scientist to him, he emphasizes the inappropriate publication method and the lack of productivity or narrow focus of scientific inquiry as a rationale for his refusal to accept Rachel Carson as a scientist. It is interesting to contrast the rationale he gives for his resistance to Mae and Rachel as scientists with the rationale he provides for accepting Kathleen Dudzinski as an interesting scientist, despite the fact that she didn't meet his criterion of a scientist who studies "ten or four things". His comments below suggest the relevance of his interest and knowledge of dolphins:

Interviewer:	Do you remember the story about Kathleen, the scientist who studied dolphins? Did you find she was an interesting scientist?
Raja:	Yes
Interviewer:	Why?
Raja:	Because I know I like dolphins and I know how they communicate. They use sounds
Interviewer:	Did you find that she was an interesting scientist?
Raja:	Ya
Interviewer:	Did you find that an interesting story?
Raja:	Ya
Interviewer:	Why? What was interesting about that story?
Raja:	The dolphins

Students interpret counter-stereotypic images of scientists against a backdrop of previously acquired images of scientists and various social categories including gender, ethnicity, age, etc. Raja's stereotypic images of scientists and his theories of Black people and females may have been responsible for his resisting acceptance of Mae Jemison and Rachel Carson as scientists. Similar resistance was noted by Gayle Buck, Diandra Leslie-Pelecky, and Susan Kirby (2002), who found that despite having female scientists visit grade 4 and 5 students and show them video tapes of their "labs", the majority of students after eight visits over a 3 months period, described the scientists as "teachers" rather than scientists. The rationale students provided for their reluctance to see the female visitors as scientists pertained to the physical appearance and behaviour of the visitors. Students asserted that the visitors were not scientists because they were not wearing lab coats, glasses and gloves, did not look old and did not conduct real experiments and talk about "complicated things".

Part two: students' views of the nature and purpose of scientific work

At the beginning of the study, the most prevalent perception of scientific work and the purpose of science was to produce "stuff" such as potions, buildings, technical devices and "even nature itself". All but one student described "making or building" things as one of their images of scientific work, and for several students this was perhaps their central image (i.e., the first image they describe and the one they provide the most examples for). Even when students talked about scientists conducting experiments, further probing yielded the notion of making either potions, a technical device (e.g., robot) or an alien. The following pre-interview excerpt with Faruq captures this image:

Interviewer:	What are scientists?
Student:	They make something
Interviewer:	Like what?
Student:	Like dangerous stuff
Interviewer:	Anything else?
Student:	And experiments
Interviewer:	What kind of experiments do they do?
Student:	Make something
Interviewer:	Like what?
Student:	Like an alien

Students' emphasis on making or building things is a divergence from the prevailing image of scientists as "chemists" in previous research (Finson 2002). It is important to point out that when the majority of students talked about scientists "making things" they did not communicate a view of scientific work that included an element of design or intervention. In other words, they did not present scientists as designers with an interest in producing a product or an artifact with a specific purpose in mind (i.e., engaging in technology). Only one student in the study communicated an image of "design" as part of the work of scientists, by depicting a scientist involved in designing a special robot that could build a house surrounded by water.

Students' views of the purpose of scientific work as involving the production of concrete products is similar to the view Anastasia Elder (2002) found was expressed by 30% of the grade 5 students involved in a hands-on, inquiry-based science program. Similarly, the view that scientific work is largely "activity-oriented" rather than involving cognitive processes such as problem solving or designing was also observed by Carol Smith, Deborah Maclin, Carolyn Houghton and Gertrude Hennessey (2000) among grade 6 students. These authors examined the epistemological ideas about science in two classes—one taught in a constructivist manner and the other using a more traditional approach. They found that in the control class, 67% of grade 6 students viewed "doing things" as the primary goal of science while in the constructivist class only 27% reported this view. This suggests that this "activity-based" or "hands-on" image of scientific work is experientially determined rather than developmental.

Consistent with the emphasis students expressed at the beginning of the study on the "physical" or "activity-oriented" dimension of science (i.e., the making or building of things) is the emphasis 3 out of 11 students ascribed to the term "discovery" in their description of the work of scientists. For these students, the notion of discovery was associated with finding, for the first time, a concrete aspect of nature (country, animals, outer space). This view of the purpose of science was also expressed by many of the 11–14 years old students studied by Solomon et al. (1994). Similarly, Edna Rubin, Varda Bar and Ariel Cohen (2003) also found that approximately half the pre-service teachers in their study defined Columbus as a scientist.

By the end of the study, students' views of the nature of scientific work were broadened to include cognitive processes such as thinking, guessing, wondering, asking questions, observing, although this view did not replace some of students' pre-study views. Students continued to include making and building structures and potions as examples of scientific work. At the end of the study, all eleven students described the purpose of scientific work as involving "figuring things out" or studying/learning about either nature in general or specified aspects of nature.

Two excerpts from Mala's pre- and post-interview provide an example of how students broadened their image of the kind of things scientists do to include cognitive work. In her pre-interview, Mala begins the study with an image of scientists that includes making and doing tricks:

Interviewer:	What are scientists?
Student:	They do like scientist's stuff
Interviewer:	Like what kind? Can you tell me a little bit about that?
Student:	They can make cakes
Interviewer:	What other kinds of things do scientists do?
Student:	Doing tricks
Interviewer:	What kind of tricks?
Student:	Like disappearing stuff

In her post-interview Mala reveals that she has broadened her view of scientists to include asking questions and making books:

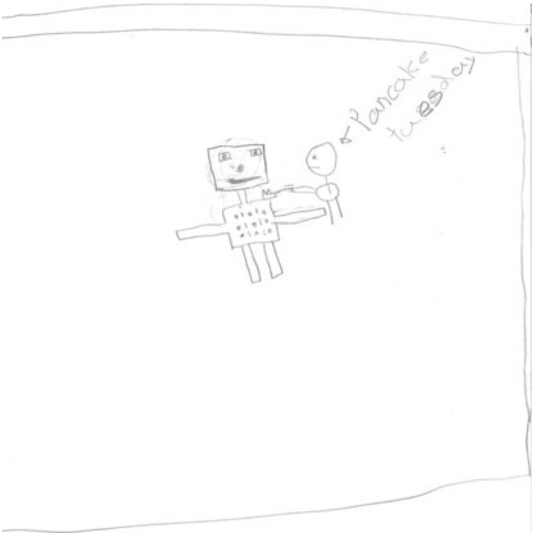
Interviewer:	What is a scientist?
Student:	A scientist is a boy or girl and it makes things
Interviewer:	Like what kind of things?
Student:	Books. And they ask so many questions
Interviewer:	About what?
Student:	About chimpanzees and dolphins and animals

Data from the DAST suggest similar changes in students' images of the nature of scientific work. The pre- and post-DASTs (Figs. 2, 3) by a male student provides an additional example.

A story by Raja features a scientist who "studies" why fires react, "thinks of a way in his mind" and then "tests" or explores this question empirically. Although it is not very clear from his story how exactly he is exploring this question, it nonetheless provides an example of a scientist engaged in work with the purpose of making sense of natural phenomena (he provides an example of his question, some empirical work and theorizing):

> Once there was a scientist. He was studying about …why does fire react like it's real when it's not real. So then he thought of a way in his mind. Then he thought of why didn't he make a potion and then test it on a fire to see why does it react. So then he made a potion of fire and then he put it on fire somewhere and then he react…he put it on this thing and he looking at it…What makes the fire react? And then he found

Fig. 2 Julian's pre-DAST: "He is building a robot"



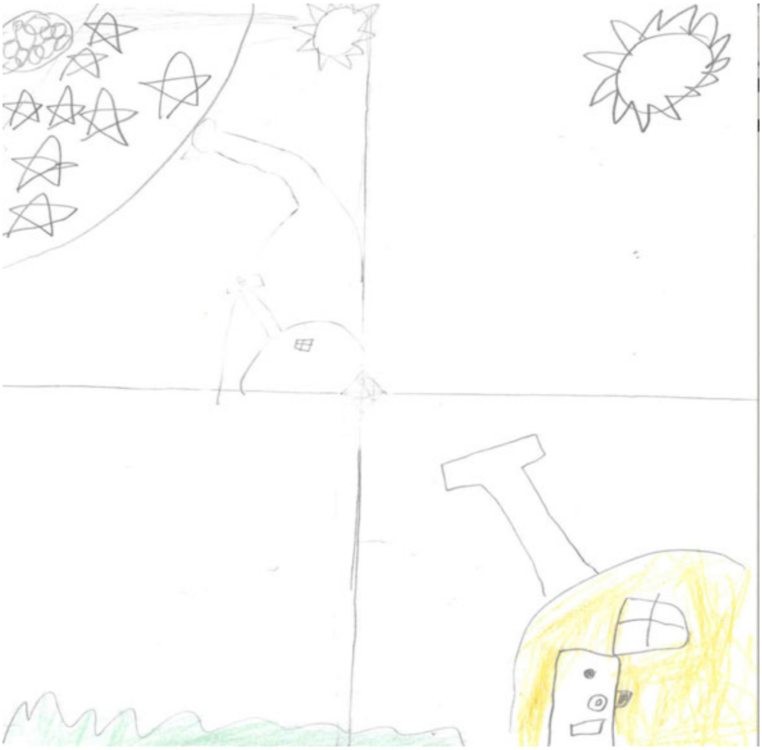


Fig. 3 Julian's post-DAST : "The scientist is inside the observatory. He's thinking how are the stars more hotter than the sun?"

> the fire reacts because it moves …and the wind pushes it to act like a drill…and he said, "I think…"
>
> What did he think?
>
> He think I have to do more studies. So he did another study and then he used it…why don't they grow in sand. So, why doesn't flower grow in sand and why does it grow in soil? And he was like – in soil, I guess it will grow faster but why doesn't it grow in sand. But then he found out: probably because they need sea water for the sand to make it grow. So then he test it and after a few days later it grow into a flower…

Students' views of where scientists work

Another important dimension of scientific work is where scientists work. Although, numerous studies have indicated that the single most common location where students depict scientists working is the laboratory (Barman 1997), only 3 out of the 11 students (Faruq, Raja, Kamala) expressed this view at the beginning of the study. However, at the end of the study an additional 2 students (Shruti, Skyla) described the lab as a place where scientists work.

Since none of the scientists featured in the stories worked in a lab, one explanation for this subtle change might be that these students appropriated this word from our whole class discussions concerning the stories about scientists. Another possible explanation derives from the following excerpt from Skyla's post-interview where she reveals an unusually broad conceptualization of the word "lab". This excerpt also underscores the complexity of ascertaining children's thinking and the value of encouraging them to elaborate and provide examples of specialized terms related to scientific work (e.g., lab, experiment, discovery):

Interviewer:	Okay, what kind of places do scientists work?
Student:	In a lab
Interviewer:	Is that the only place?
Student:	Ya
Interviewer:	Where did Rachel work?
Student:	Rachel work in her house
Interviewer:	So did she work in a lab?
Student:	I got a lab at my house; it's my room
Interviewer:	What about Mae, did she work in a lab?
Student:	A little bit because the rocket ship is like a lab

By the end of the study, all students with the exception of one (i.e., 10 students) expressed the view that scientists can work "outside" (an additional 6 students compared to the beginning of the study). Moreover, by the end of the study, all students acquired additional images of the nature of indoor and outdoor locations where scientists can do some of their work. My notes from a class discussion provide some examples: forests, ocean, different places around the world, Earth, outer space, rocket ship, college, observatory, Africa, jungle, at home, garden, library, office. The responses of three students, when asked in their post-interview where scientists work, suggest that they acquired a very flexible view of the location of the work of scientists: "Like in any country or anywhere" (Kumar); "Sometimes in a lab or in their own home or outside" (Kamala); and "Wherever they need to go" (Julian).

Students' views of the affective dimension of scientific work

As noted by Steve Alsop (2001, p. 63), the "image of science and scientists presented more often than not embodies a sense of emotional aloofness or detachment." At the beginning of the study not one student expressed an appreciation for the affective nature of scientific work. However, at the end of the study, there were two interrelated affective dimensions of scientific work that were expressed by students: (1) affect related to the subject matter of science i.e., nature; and (2) affect related to aspects of scientific inquiry.

The first dimension centred on students' awareness that scientists could possess several "affect-related" motivations for doing science or being a scientist: interest in and enjoyment of nature, caring for nature and a curiosity about how nature "works". Seven of the eleven students expressed this view at the end of the study. For example, in his pre-interview, Faruq describes scientists as people who "make something". He makes no mention of scientists' interest in what they make or any aspect of their work. However, there is a subtle but significant change in his description of scientists in his post-interview. There, he spontaneously describes a scientist as "a person who *likes* chemicals and learns about nature." Similarly, when Raja describes a scientist at the end of the study he adds another characteristic—curiosity—to his image of intelligence or being "smart":

Interviewer: What kind of people are scientists?
Student: They are smart people and they're curious

In the following example, Renu, a female student, expresses her awareness that "liking the ocean" can be a legitimate motivation for learning about the ocean:

Interviewer: Okay. How do they spend their time?
Student: They work different things
Interviewer: Can you give me some examples?
Student: Astronauts, oceans, moons, plants
Interviewer: And what do they want to do with these things? With the ocean and plants and planets?
Student: They just want to—at the ocean they want to go down the ocean and they wanted to take pictures of the plants. They want the plants to grow
Interviewer: Okay. Why do they want to do that?
Student: Because they like the ocean and they want to learn about the ocean; What's inside the ocean?

The second dimension centred on student affect related to doing science or the enjoyment of scientific inquiry. At the end of the study, six students also expressed a notably positive attitude or stance toward specific aspects of scientific inquiry. This suggests an awareness that in addition to their passion for nature (or very specific aspects of it) scientists can also be inspired or motivated by scientific inquiry. In the following example, Fazeela tells a story of a scientist who enjoys asking questions and wants to become a scientist:

> Once upon a time there was a scientist named Judy. She loved to ask lots of questions to a scientist. When she was done she was still a scientist even when she was a baby. And she loved to play with her mom and dad and her sister. She loved to learn about nature. Every kind of thing. So, when she was in college, she said, I want to be a scientist and she thinks about everything she likes to think about.

Interviewer: What does she do as a scientist?
Student: She loved to learn about her questions

Case study 2: developing interest in the work of scientists

Shruti is a soft-spoken six-year-old girl from Sri Lanka. She participated only cautiously in large group activities but very confidently approached me and often volunteered to share stories about scientists she made up independently. Her ability and confidence in science and interest in stories were described by her teacher as “average”. She enjoyed listening to the stories and expressed an interest in hearing more stories about scientists the following school year.

In contrast to the other participants, Shruti expressed a lack of interest in science at the beginning of the study, pting to use the word “hate” rather than just “no” to describe her disinterest in becoming a scientist. An excerpt of her pre-interview captures this lack of interest:

Interviewer: Would you like to be a scientist?
Shruti: No
Interviewer: Why not?
Shruti: I hate it
Interviewer: Why do you hate it? [silence]
Interviewer: What do you hate about being a scientist?
Shruti: You have to build something
Interviewer: Is there anything in science that you like?
Shruti: Drawing and painting
Interviewer: Drawing and painting what?
Shruti: Houses and boats and islands with polar bears in it and whales and dolphins

Despite the fact that there were aspects of science that Shruti likes—namely drawing and painting—she still “hated” the idea of being a scientist. This could be interpreted two ways. First, she may associate building, drawing and painting with the work of scientists but consider building as the most significant or central work of scientists. Another possible interpretation is that she may have distinguished in her mind between the work of scientists and the work involved in school science—considering building as part of scientists’ work but drawing and painting as something you do in school science.

In an excerpt from her pre-interview, Shruti’s first description of scientists centres on their work: “they build things”. This seems to support the notion that for Shruti, building is a main or central image of scientists’ work. It is only with further probing that she considers painting and drawing.

Interviewer: What are scientists?
Shruti: They build things
Interviewer: Like what?
Shruti: Like robots
Interviewer: Anything else? Is there anything else, other than building things, that they do?
Shruti: Paint. Draw
Interviewer: What kinds of things do they draw?
Shruti: Houses, islands, planes

By the end of the study, Shruti expressed a more broadened image of what scientists do. She no longer includes "building things" in her description of scientists' work but has acquired another image not expressed by the stories: making potions. I suspect she appropriated this image from our group discussions after hearing a few children make reference to scientists as people who make potions. Nonetheless, her response in the post-interview excerpt below conveys a richer understanding of what scientists do:

Interviewer: What is a scientist?
Shruti: A scientist asks questions and do lots of experiments with a group of scientists and write it down on a notebook what they really see that is dangerous or safe or interesting…Scientists ask questions and do potions and think how to answer questions…

Similarly, her picture of a scientist in her post-DAST also captures the spirit of inquiry—"wondering" about nature. However, by the end of the story, Shruti not only broadened her conceptualization of what scientists do but also expressed an interest in science which was clearly not there when the study began. In her post-interview, Shruti explicitly expresses her interest in becoming a scientist:

Interviewer: Would you like to be a scientist?
Shruti: Yes
Interviewer: Are you a scientist now?
Shruti: We're learning like a scientist
Interviewer: Like what are you doing?
Shruti: We're asking lots of questions and we're thinking how to answer it.

Shruti's broadened conception of the nature of scientific work which included asking and trying to answer questions about nature seemed to act as a resource that increased her interest in becoming a scientist and allowed her to form a more positive identification with science.

Case study 3: losing interest in the work of scientists

Skyla is a seven-year-old student in grade one who speaks Tagalog at home. She is described by her teacher as very confident and an "above average student" in science. Similar to Shruti, Skyla broadened her ideas about the kinds of things scientists do (e.g., ask questions, write papers, work with a team of researchers). However, in contrast to Shruti who experienced an increase in her interest in science as a result of her broadened conception of the kinds of things scientists do, Skyla's new image of the work of scientists led to distancing her imagined future self from the work of scientists.

It is interesting to note that, unlike Shruti who had a more restricted or narrow image of what scientists do, Skyla's images of science and scientists were similar to Raja's in that they were more extensive and contained more traditional stereotypes than the other participants. In her pre-interview, she described scientists as people who experiment, and when encouraged to elaborate on what the term "experiments" means to her she gave "making electricity", "taking care of animals", "experimenting with animals" and "turn[ing] them into different animals"as examples. Skyla clearly drew heavily on her exposure to television when she described her image of a scientist as a 'maker of nature", and more specifically when she asserted that scientists can make real boys and girls:

Interviewer: There's a scientist that's done that? That's made a *real* boy and girl?
Skyla: Ya. I watched it in the movies
Interviewer: And they made a boy and girl? How did they make them?
Skyla: With sugar and spice and everything nice and chemical X

Skyla relates this image of a scientist to the work of the scientist, Professor Utonium in the movie, *Power Puff Girls*. In addition to some of the more stereotypical images of scientists she describes, Skyla explicitly asserts several kinds of science: "There is lots of science you can see- science of animals, science on space" and in her pre- and post-DAST, Skyla drew a picture of a paleontologist digging up dinosaur bones. However, although Skyla began the study with an extensive "library" of images of the kinds of things scientists do—some of them obviously very stereotypical—her expressed interest in science centred on "making dolls":

Interviewer: Would you like to be a scientist?
Skyla: Ya
Interviewer: What would you like to do as a scientist?
Skyla: Make dolls

At the end of the study Skyla described scientists as people who "make robots"; "discover animals"; "learn about nature and learn about monkeys"; "some study under-animals, underwater animals. Even some nature like birds and plants". Later in the interview, however, Skyla explains that she would not like to be a scientist and suggests that this is due to the amount of work she thinks scientists have to do:

Interviewer: Would you like to be a scientist, Skyla?
Skyla: No
Interviewer: Why?
Skyla: Because they have to do a lot of experiments even they have to try to nature
Interviewer: Like what do you mean they have to try nature?
Skyla: They have to do a lot of work
Interviewer: Like what?
Skyla: Like they have to discover nature, have to try to have a team. Even they have to get a paper to write so—They do a lot of things-they make robots; even us

The ideas she associates here with the "hard work" scientists have to do are drawn clearly from both her prior conception of science (i.e. experiments, discover nature, making robots, making "us") as well as ideas expressed in the stories presented in class (write a paper, work with a team). Although it is not very clear which aspects of scientific work are responsible for Skyla positioning herself at the end of the study as an "outsider" to science, there are a few possibilities. First, it is possible that Skyla misinterpreted the diverse images presented as suggesting that *all* scientists *have to* engage in *all* the tasks and activities featured cumulatively throughout the stories; if that is the case, it's no wonder that she would think that the work of a scientist is "too hard". Another possibility is that Skyla's interest in "making dolls" was not legitimated in any way by the stories featured in the study.

Although it is difficult to say, perhaps the most relevant point here is that students' interest in science can be negatively impacted by their views of scientific work and we can never know in advance how students will respond to particular stories or a collection of stories that portray science in a particular way. Students' interpretations of stories are shaped by their unique experiences and idiosyncratic interpretations. What we can do, however, is pay attention to their emerging views and emerging interest or lack of interest and consequent positioning in science in an effort to make science accessible to all students.

Reflections

Narrow, exclusive images of science and scientists not only misrepresent the nature of science and the scientific community but are also one of the reasons why many students distance themselves from school science. Because most children experience limited contact with real scientists, the main source of their images of scientists and what it means to do science is often the media, including, for example, television, videos, books and magazines. Since the majority of the images in popular media are stereotypic, children need access to resources that promote diverse images of who can do science, the kind of work that scientists do and the environments where scientists work. In this study, stories that featured scientists from diverse backgrounds, engaged in diverse forms of work that included a cognitive dimension (e.g., asking questions, predicting, creating theories), a social dimension and an affective dimension (e.g., curiosity, interest in various aspects of nature and scientific inquiry) were used, in conjunction with reflective activities, to assist students to add to their kaleidoscope of images of scientists and scientific work. In this section, I reflect on how the stories about scientists and follow-up reflective activities were productive in helping students broaden their views of scientists and their work, the ways they were more limited in doing so and the features of the stories and activities that may have mediated positive changes in students' view.

Providing students with counter-stereotypic examples of scientists

Helping students acquire counter-stereotypic examples of scientists was one of the ways the stories and follow-up activities assisted students in broadening their views of the kind of people who can be scientists. While at the beginning of the study not one student was able to name a scientist (aside from fictitious ones in the media), at the end of the study, all were able to provide names of one or more scientists from less dominant sociocultural groups. Since all the scientists named by students were featured as part of the study, it seems fair to assume that the stories presented to students were the source of these images acquired by students. The specific examples acquired by students as indicated by students' differential recall of the scientists in their post-interview seemed to be influenced by student interest in the topic studied by the scientist featured in the story. As suggested by the interview excerpts below, the rationale often given by students for why they found a particular story interesting centered on the subject matter studied by the scientist:

Interviewer: Which of the stories did you find the most interesting?
Student: Stephen Hawking
Interviewer: Why?
Student: Because I like black holes

Even when students were explicitly asked about which scientists they found most interesting their response drew on their interest of the science topic studied by the scientist:

Interviewer: Which of the *scientists* did you find the most interesting?
Student: Mae and the dolphin story
Interviewer: Why did you find those interesting?
Student: Because Mae was learning about outer space. I like outer space and I also like dolphins

These excerpts suggest that it may be the case that students' identification with the scientist featured in the story may not necessarily pertain to such salient sociocultural characteristics as their gender, ethnicity and physical ability but to the subject matter studied by the scientist. This means that, while it is important to locate stories about scientists from under-represented sociocultural groups, the research focus of the scientist should be an additional consideration.

Challenging students to reconsider their exaggerated views of the intelligence of scientists

While studies have indicated that students view scientists as being exceptionally intelligent or smarter than most people (e.g., Mason, Khale and Gardner 1991), there is limited research that provides insight into interventions effective in modifying these views and helping students view scientists as representing a range of "intelligences". Students' views at the beginning of the study provide a preliminary glimpse into some of the different ways in which students conceptualize the "superior intelligence" of scientists (i.e. involving knowledge, skill, infallibility and discovery). Gains made in students' images of the "intelligence" of scientists suggest that the stories encouraged students to reconsider their view that scientists "know everything". Some of the students were able to articulate reasons for their post-study awareness that scientists "don't now everything". For example, when asked during his post-interview why he thought scientists did not know everything, Faruq remarked "because they ask a lot of questions". Another student justified her thinking by using a similar line of argument, noting: "they can't find the answers from the book or the computer and the magazines" (post-interview, Shruti). These comments suggest that students' reconsideration of one of the stereotypic characteristics commonly attributed to scientists—their "genius-like intelligence"—may have been mediated by an emphasis on scientists engaged in the *process* of science rather than the finished *products* of science. Thus, when sharing stories with students about scientists, it may be helpful to portray scientists *doing* science rather than just focus on their scientific achievements.

Broadening students' views of physically challenged scientists

Another way that the stories about scientists seemed to have helped broaden students' images of scientists was in helping them recognize that wheelchair-bound and blind people can be scientists. This is relevant, as much of the research on extending students' images of scientists has emphasized gender and ethnicity as the primary identity markers; few have explored resources that help students recognize that people with a variety of physical challenges can be scientists. Two possible features of the stories may have mediated this development: (1) providing students with examples of scientists with physical challenges (e.g., Stephen Hawking and Geerat Vermeij); and (2) students' increased appreciation for the central role played by cognitive processes such as generating questions, predicting and trying to make sense of phenomena, in scientific inquiry. When asked for example, how it could be that Stephen Hawking is a scientist, Raja, indicated, "He couldn't speak but he could ask lots of questions…".

It is also interesting to consider why more students expressed a view of scientists that included wheelchair-bound people over one that included blind people. This difference may be due to students' belief that vision is a more important requirement for scientific work than mobility. An additional factor could be that the story about Stephen Hawking was more convincing as it was told using a video with many colourful and powerful images of Stephen, the university where he works and images of outer space that students readily associate with science. This is consistent with results from research which found that counter-stereotypic symbolic models in film produced a more significant and enduring reduction in preschool children's stereotyping than picture books (Flerx, Fidler and Rogers 1976). It may also be relevant that while 6 students made reference to Stephen Hawking's story as one of their favourite stories at the end of the study, only 2 students referred to the story of Geerat Vermeij, a blind scientist, as their favourite. Further research that documents attempts to help students appreciate that people with a range of physical abilities are capable of being scientists is clearly needed.

Broadening students' views of the nature of scientific work

In addition to extending students' views of scientists, the stories about scientists presented to students were productive in broadening students' views of scientific work, from a predominantly hands-on/activity-oriented view to one that includes cognitive and affective dimensions.

Previous research (e.g., Elder 2002) suggests that many older students (grades 4–6) perceive science, and correspondingly the goal of science, as "activity-oriented" (viewing the nature and purpose of scientific work as "doing things" or making stuff) rather than involving a cognitive dimension (including thinking, developing and testing ideas). This indicates that the "activity-oriented" views expressed by the grade 1 students at the beginning of this study were not necessarily constrained by their developmental level. Meditational strategies that were strategically used to assist students in using the stories to appreciate the cognitive dimension of scientific work included: portraying the scientists in the stories asking questions, formulating predictions and considering theories; using symbols that represented 'thinking' for most students such as the thought bubble included in a follow-up worksheet where students were encouraged to record the scientist's questions and thinking; and large-group follow up activities that highlighted connections between the questions and theories of the scientists featured in the story and those of the students.

It is important to note that, since students selectively attend to aspects of a story which may not relate to the intended goal of the lesson, without teacher guidance or mediation, students could potentially walk away from listening to stories without meaningful developments in their views of scientists and scientific work. For example, students were told, before the beginning of the story about Kathleen Dudzinski, that the purpose of the lesson was to learn about scientists and the kind of work they do. Throughout the story, students were also encouraged to consider various aspects of Kathleen's work, such as where she was working, the kinds of questions she asked, who she worked with and so on. Nonetheless, at the end of the story, when asked what they learned from the story, some of the students' responses included: "I learned about how dolphins talk"; "I learned that dolphins have fins and they play with each other". These responses suggest that the focus of their attention was on the science content featured in the story. It was only after completing, with students, the large-group follow-up chart (see Appendix 2) which emphasized Kathleen's background, what she did, the questions she asked and where she worked, were students' responses to the question of what they learned, more consistent with the goals of the lesson: "I learned that Kathleen was looking at the dolphins and listening to their sound"; "I learned about dolphins and the scientist—that she likes the dolphins and the ocean because they're cute and playful. She has two sisters and a family. She was trying to answer all about the dolphins".

As noted by Alsop (2001), the image of science and scientists prevalent in dominant school science discourse is one of emotional aloofness or detachment. At the end of the study, many students expressed a view of scientists that highlighted their interest and enjoyment of nature and various aspects of scientific inquiry. This suggests that one way of potentially challenging the "archetypal dispassionate rationale and emotion-free image of science"(Alsop 2001, p. 67) might be to personalize science by giving it a 'human face' through the use of stories about scientists who are curious, interested and care about nature and their work.

Shifts in student interest in science

Skyla's and Shruti's cases illustrate how assertions about the nature of scientific work (i.e., the kind of work that scientists do), even when they are considered diverse and inclusive by our standards, can trigger an affective response in students and influence whether or not they consider science as meaningful work in which they can see themselves actively participate. Both Shruti and Skyla seemed to have experienced a shift in interest in science as a result of a change in their conception of the nature of scientific work: while Shruti's view at the end of the study helped her position herself as an insider in science, Skyla's understanding positioned her on the outside.

Although I hold out hope that Skyla will continue to develop her conception of science and encounter opportunities that will afford her insider status to science, her case raises important questions about teaching primary students *about* science. For example, what aspects of the nature of scientific work communicated to students would facilitate the most interest and engagement in science at the grade one level? Are there some aspects of scientific inquiry (e.g., working collaboratively, empirical work, asking questions, communicating findings) that can either increase student interest in science or make them feel uncomfortable at this level? And, what factors (i.e., personality, gender, previous experiences with science, academic strengths, personal interest, ethnic background) influence how comfortable students feel with various notions about the nature of scientific work highlighted through stories about scientists and other means?

While this study does not provide answers on how to ensure that all students feel comfortable with ideas advanced about the nature of scientific work, it does provide examples of how notions about the nature of scientific work can impact student interest (both positively and negatively)—even at the grade one level. This awareness can lead to intentionally providing students with the space to discuss how they feel about ideas about science that are communicated through stories and other activities in the science classroom, which in turn, may lead to the design of creative and appropriate scaffolds to ensure that all students develop positive views of science.

Changes in students' views of the gender and ethnicity of scientists

In comparison to the changes noted in students' views of the aforementioned characteristics of scientists and dimensions of scientific work, the evidence was less clear that students had experienced significant changes in their views of the ethnicity and gender of scientists. This may be, in part, because changing students' stereotypes of the ethnicity and gender of scientists may involve modification of existing theories related to various ethnicities and the female gender, in addition to their theories or stereotypes of scientists. Moreover, students draw on preexisting conceptions including any racist and/or sexist cultural models they may have appropriated to interpret stories and other text.

Raja's resistance to the counter-stereotypic images presented through Mae Jemison's and Rachel Carson's stories of scientists illustrates a potential challenge of using stories about scientists from less dominant groups to extend students' images of scientists. The fact that Raja also had one of the most extensive and stereotypic images of scientists of his peers supports the assertion made in the literature that the more extensive students' stereotypic images of a social group, the greater the likelihood that resistance will take place and, therefore, the more challenging it may be to modify students' views.

The lack of clear evidence that students developed more egalitarian views of the role of male and female scientists also point to the complexity of modifying students' views of gender roles in science. For instance, even when students in this study depicted female scientists, it was not uncommon for them to portray them in secondary roles relative to male scientists. A similar biased perception between male and female scientists was also documented by Rosenthal (1993) who found that when liberal studies college students drew pictures of both male and female scientists, there were obvious differences between them—male scientists were drawn with knowledge symbols such as pens and pencils whereas female scientists were drawn with decorative accessories such as ribbons and beads. Hence, in addition to paying attention to whether or not children depict scientists as females, these data suggest that we should pay close attention to the nature of students' representations of female scientists. For example, how similar or different do primary students see female and male scientists? Are female scientists seen as capable of doing only certain kinds of science work? Are they seen as just as smart or knowledgeable as their male counterparts? Do students perceive female scientists as capable of doing work of comparable significance?

Facilitating an inclusive understanding of scientists and science and generating positive attitudes toward scientists, the work scientists do, and school science, are important goals for an equitable and engaging science education. Despite the complexities illustrated by Raja's and Skyla' cases, many of the changes in students' views documented in this study suggest that stories about scientists can help 'humanize' science and extend students' images of who can be a scientist and what it means to do scientific work—although, it is worth noting that for more comprehensive and meaningful change, such efforts should be embedded in a multicultural science education framework (see, for example, Hodson 1999), that helps students appreciate, in developmentally appropriate ways, the sociocultural, historical and political contexts of science. As children develop more inclusive images of science and scientists and a heightened appreciation for the sociocultural nature of science, they are creating links that have the potential to be both informative and transformative for their developing sense of self, as individuals and as potential members of our future science community.

Appendix 1: summary of stories about scientists presented to students

The story of Kathleen Dudzinski

Resource used: Meeting dolphins: my adventures in the sea (Dudzinski 2000)

This story features Kathleen's interest in animals as a young girl and her growing interest in learning about and working with animals in school. It describes her learning to collect data on dolphins (e.g., taking pictures using a special underwater camera, keeping track of the same dolphin over time). The story features her working with a group of scientists on a boat and emphasizes her questions about dolphins. She works with a group of scientists to help her answer her questions: How do dolphins know whose turn it is to lead when they change direction?; Does one dolphin start the turn or do they turn together as a group?; If there doesn't seem to be a leader, how do they signal to one another?; How do dolphins communicate?

The storybook shows her using special underwater cameras to record the sounds and visual signals of the dolphins and a computer to replay these recordings. The story highlights how reviewing the data and thinking about it can result in more questions: if dolphins use the same signals during different activities do they mean the same or different things? The story also highlights her hypothesizing: When she recorded dolphins biting and hitting their teeth on one another and making loud whistles she had a feeling that some of the time this was play and sometimes it was fighting, but she couldn't figure out which it was. The story ends by revealing the inspiration behind her theory that dolphins roll over one another when they play (i.e., through watching puppies play-fighting).

The story of Jane Goodall

Resources used: Jane Goodall: a life with animals (Ferber 1997) & the video, Jane Goodall: my life with the chimpanzees (National Geographic Society 1997)

This story begins with a look at Jane's life as a young child. It marks an important event in her childhood which led her to dream of travelling to Africa—her reading the story, *The Story of Doctor Do little*—the story about a veterinarian who learns how to talk with the animals he took care of. This event is also highlighted as the beginning of her interest in reading about animals. The video features Jane watching the chimpanzees, taking notes on what she observes, giving the chimps names and interacting with them as a way of learning about them, and asking questions about them: How do the mothers take care of their young? How do the chimpanzees play with each other? The video also features Jane in a teaching role at the zoo, answering people's questions and talking to groups of children at school. She is portrayed as a scientist who is committed to the future welfare of the animals she studies—not just someone interested in studying them.

The story of stephen Hawking

Resources used: Stephen Hawking: understanding the universe (Sakurai 1996) & the video, Stephen Hawking, the universe within (Hawking 1989)

The storybook and video provide a glimpse into the childhood of Stephen: his keen sense of curiosity, his interests (e.g., playing with toys, taking things apart), his family life (younger siblings) and his struggle to do well in school (he didn't learn how to read until he was 8 years old and had sloppy handwriting). The story highlights the differences between his father's desire for him to become a doctor and Stephen's interest in studying mathematics and science. Two important events in Stephen's life are highlighted in the story: becoming ill and meeting a good friend, whom he later married—both of which inspired him to study the science he was fascinated by and become a more productive student. The latter theme highlights the importance of friendship and being motivated to study and work. As an adult, Stephen, the scientist, is also portrayed in his role as a parent of three children. The video images of black holes and other aspect of the galaxy were aesthetically appealing and gave students a glimpse into one aspect of Stephen's work. Stephen's questions are considered an important part of his work: How did the universe begin? How long do black holes last?

The story of Mae Jemison

Resource used: Mae Jemison: space scientist (Sakurai 1995)

The story begins with an emphasis on early years—her family life and her wide range of interests as a young child (African dance lessons in grade 3, science, reading about many things). It highlights her dream of travelling into outer space. She first becomes an electrical engineer and then a doctor and finally an astronaut. Her interest in helping people through her work is emphasized by telling about her work as a doctor in developing countries as a doctor. Her continuing wide range of interests and hobbies as an adult and a scientist are emphasized: playing with her cat, reading, travelling, skiing, working on her garden, dancing and exercising. Mae is featured working with a team of scientists, constructing questions they will try to answer while they are in outer space. For example, they wanted to know why people lose bone tissue when they're in space. They also wanted to find out if tadpoles develop into healthy frogs when they hatch in outer space. They did an experiment and found out that they did. The excitement of answering a question for which they had no previous information is emphasized.

The story of Rachel Carson

Resource used: Rachel Carson: writer and environmentalist (Burby 1997)

Nature is depicted as playing an important role in the childhood of Rachel Carson. Her love of nature from early childhood is illustrated by showing her exploring the river and the woods with her mother, asking her mother questions and learning the names of different birds and flowers. She learns from an early age to respect and care for nature. Rachel's love for writing initially leads to her wanting to become a writer. However, following a particularly enjoyable science class in college, she decides to become a scientist. Rachel is featured as a scientist who not only studies nature (the ocean and animals near the sea) but communicates her findings to the public through magazines, newspapers and books. The story concludes with a look at Rachel's work with DDT : questioning the health risks of DDT, collecting evidence that DDT was killing animals and writing a book about it. The public's lack of acceptance of her ideas is showcased, along with the eventual triumph of Rachel's ideas (with the help and support of others).

The story of George Washington Carver

Resource used: A weed is a flower: the life of George Washington Carver (Brandenberg 1965)

Some of George's struggles as a child are explored at the beginning of the story: the death of his father when he was a baby and living in poverty. As a child, George is depicted as a curious child who asked many questions about everything around him: rain, flowers, and insects and who has a wide range of interests, especially in plants. George is depicted as a resilient person who, despite his poverty, works hard, saves enough money to go to college and studies science. As a scientist, George continues to enjoy many of his childhood interests: singing, playing the piano and painting. George's work involves trying to find ways to make plants grow better. The relevance of George's work to his community is highlighted by how he helps the farmers in his neighbourhood solve problems with their cotton plants: he wondered if maybe they were having problems because they were planting cotton every year in the same soil and not giving the soil a chance to regain some of its nutrients. He encourages the farmers to try planting different plants such as peanuts and potatoes to test out this idea. The problem is solved when the farmers try this and the community learns a better way of farming.

The story of Fred Begay

Resource used: Native American scientists: Fred Begay, Wilfred F. Denetclaw Jr., Frank C. Dukepoo, Clifton Poodry, Jerrel Yakel (St. John 1996)

The story begins with a portrayal of Fred as a Navajo Indian and scientist who works in a laboratory in New Mexico but returns regularly to his Navajo community to meet and share his learning with his people. Fred's observance of some aspects of his culture is highlighted—he is shown conversing with a medicine man on a Navajo reservation in the desert wearing traditional clothing. Fred is portrayed as having an interest in the sun and stars, animals, hunting for his family and spending time with his community. Fred was very excited about science because it helped him understand nature. Because he was quiet, people thought he was stupid or afraid, which made Fred angry. He continued to study because he loved what he was learning. Like Stephen Hawking, he studied mathematics and space science in university. He designed experiments that were sent to space in rockets. Fred wants to learn more about heat coming from sun. He is trying to find a way to produce heat without harming the environment. He is trying to copy the way the sun works to bring heat and electricity to reservation homes.

The story of Geerat Vermeij

Resource used: Privileged hands: a scientific life (Vermeij 1996)

Geerat's childhood begins with a depiction of his family—parents and older brother, Arie. He was born in the Netherlands. Early problems with his eyes led to blindness when he was a young child. The story emphasizes Geerat's determination and resilience to overcome his health struggles. His parents are portrayed as very compassionate but firm and as always having faith that Geerat is just as capable as other boys of doing important work. He goes to a special school for the blind where he learns how to read and write Braille. One of the important events in his early life was when his grade 4 teacher brought her shell collection to school. This sparked his interest in shells. After this experience Geerat started to wonder about shells: why some shells were smooth and others rough, how they protected themselves and how they change over time. As a scientist he still tries to find the answer to these and other questions about shells. He finds them very beautiful and marvels at how many different kinds of shells exist in the world. Geerat is also portrayed as a scientist with a keen interest in travelling, reading and writing and talking to people.

The story of Khalil Singh and Judy Kamala (a grade 3 class was guided in the construction of this story)

Khalil and Judy are scientists born and living in Sri Lanka. The family and personal interests of both scientists are described: Khalil was a middle child with 2 older sisters and 3 younger brothers. He loved painting and helping his mother cook. Judy had one older sister. She enjoyed learning how to play the sitar. Both Khalil and Judy loved reading books in Hindi and English. When they were in elementary school they both had a lot of questions about plants—what made plants different colours; how plants grew; why some plants grew better in some countries and climates than others. They worked together at the university in Sri Lanka where they studied plants and taught classes about them. One of their experiments is described in the story: Khalil had noticed during one of his travels to the desert that some plants grew in the sand. All of Judy's experiences had involved working with plants that grew in moist soil. So, when they found seeds that they wanted to learn more about, Khalil guessed that the seed would grow in the sand while Judy thought it would grow in the soil. They planted a seed in a labelled pot of each and observed and recorded the seeds growth for several weeks. They found that the seed grew in the soil but not in the sand. They tried to explain why this was so.

Appendix 2: Large-group follow up chart

Name of scientist
What kind of a person were they?
What were they curious about?
What questions did they have?
What did they do to answer their questions?
Where did they work?
Who did they work with?

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