Changing children's views of science and scientists through school-based teaching

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Received 19 Apr., 2007
Revised 19 Jun., 2007

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Abstract

Stereotypical views of scientists portrayed in the media, and how science is currently taught in Australian schools, both contribute to many students not studying science beyond Year 10. Reports on the status of science teaching in primary schools still tend to focus on the individual teacher's lack of confidence and inadequate content knowledge, and the limited resources available to support science teaching. To date few studies have examined how pre-service teachers engage with science content and pedagogy. From a cultural-historical perspective, the data in this study took three forms. Firstly, children's drawings of scientists were collected. Secondly, children's comments about science before and after a teaching sequence in science were documented. Thirdly, pre-service teachers' reflections on the changes in children's views after the teaching sequence in primary classrooms. Data analysis showed that when each child is valued in a communal context, and engages in relevant, hands-on science activities, the children's views of scientists are challenged, with some beginning to see themselves as rudimentary scientists.

Introduction: Identifying the problem

In popular culture several stereotypical views of scientists have been identified (see below) that represent scientists in negative terms. Unfortunately, many middle school students hold these stereotypical views of scientists, show little interest in science in the classroom, and consequently are not attracted to science or engineering careers (see Australian Foundation for Science, 1991). In contrast, the same students eagerly embrace the latest products of science and technology (such as mobile phones, computers, ipods and digital cameras) and these hi-tech products quickly become an integral part of their lives. 'Being connected' is so important for teenagers that their mobile phones are essential accessories, enabling them to communicate with their friends anywhere 24-7. We contend that this mismatch needs to be addressed at the school level and in the science classroom in particular. A challenge for teachers of science is to provide experiences for students that debunk this stereotype that is being fostered by the media.

Stereotypical views of scientists portrayed in the media

Science fiction can be defined as “works that take a more or less scientific world-view; narratives in which events are depicted on the assumption that they are explicable within the world of physical nature as investigated by science” (Blackford, Ikin & McMullen, 1999:xii). The 'science fiction' film genre frequently portrays scientists as obsessive and addicted to their work. The classic film *Frankenstein* is a good example. The film is based on a story written by Mary Shelley (1818) at the age of nineteen, during a house party at Lake Geneva, Switzerland. As part of the entertainment, Lord Byron challenged the guests to write a ghost story. There are several interesting theories on the reasons why Shelley wrote *Frankenstein*. One theory is that the experiments of Erasmus Darwin (Charles Darwin's grandfather, 1731-1803) gave Shelley the idea for her book. “Darwin subjected many of his medical patients to electrical shocks in hopes of understanding the universal life force he was so certain existed” (Herrick, 2003: 121). Initially, Mary was slow to come up with the idea for her story, but following a nightmare she began writing the now famous novel about young Dr Victor Frankenstein who tried to create a living being, but instead created a monster.

In the story, Victor became intoxicated with the possibilities of modern science. He was so inflated and consumed with the knowledge of how to animate a human creature and did not consider the morality of his creation, or even the aesthetics. He was so absorbed in the detail of his experiments, taking care as he created each section, that he failed to consider the total effect. The scientist became so desperate to make a human being (from body parts taken from the dead in the morgue) that he did not anticipate how the monster might behave in the real world. Once created the monster threatened the very being of its inventor. The scientist became the hunted and the haunted, because he acted as if there were no boundaries to his scientific work.

The characteristics of a scientist that are portrayed in this story are Victor's obsessive character, overreaching ambition, and 'out of control' behaviour, as he later realised:

> … my work drew near to a close; and now every day showed me more plainly how well I had succeeded. But my enthusiasm was checked by my anxiety, and I appeared rather like one doomed by slavery to toil in the mines, or any other unwholesome trade, rather than an artist occupied by his favourite employment. Every night I was oppressed by a slow fever, and I became nervous to a most painful degree; the fall of a leaf startled me, and I shunned my fellow-creatures as if I had been guilty of a crime. Sometimes I grew alarmed at the wreck I had become; the energy of my purpose alone sustained me: my labours would soon end, and I believed that exercise and amusement would then drive away

> incipient disease; and I promised myself both of these when my creation should be complete. (Shelley, 1818:43)

Victor was a brilliant, yet eccentric and preoccupied scientist, who began with noble, humanitarian ideals but became so obsessed with his project that he lost sight of the negative consequences. The Frankenstein story challenges past and present scientific theories by highlighting their ethical complexity. Recent experimentation with genetic engineering makes the implicit warnings decidedly modern.

Another science fiction film, *A.I. (Artificial Intelligence),* is set in the future in a time where natural resources are limited and nearly everything is engineered or artificial. The film depicts numerous robots helping humans with every need. Scientific knowledge generates the latest invention, a prototype boy “mecha” (David) who has the irreversible ability to love. A couple accepts David as a substitute for their terminally ill son who is cryonically frozen at the time. David has been programmed to love, and is activated when his new mother, Monica, reads a special code to him. Complications arise when Monica may not be able to return his love, and David, knowing he is not human, craves to be a 'real' boy. When the real son suddenly recovers the robot boy is cast aside, to an uncertain fate.

In *AI* science has not made the world neat and tidy. The opposite is the case. Robots are treated in an inhumane fashion, particularly when they become in need of repair. The film raises many questions concerning the morality of scientists and the ethics associated with robotics. Rosaleen Love (2001) aptly describes the situation the robots found themselves in the futuristic film where Artificial Intelligence has become part of everyday life.

> Imagining the future for robots is an activity that directs attention to alternative futures, and questions present assumptions about robots, i.e. that humans control robots, where robots are neither free subjects, nor agents of their own destiny, nor intelligent like humans. (Love, 2001:583)

This film may appear far-fetched at this point in time, but roboticist Hans Moravec (1999) contends that by 2050 robot brains will begin to rival human intelligence.

In a less serious context, the comic adventure film *Flubber* focuses on a professor who invents a revolutionary, green coloured compound. He calls the new substance

Flubber because it can fly and looks similar to rubber. In this film viewers see a scientist who gets so involved with his new invention that he forgets to attend his own wedding! While most viewers enjoy the gravity-defying visual effects, they also see a scientist who is absent-minded and totally obsessed with his own experiments.

Such a naive concept of a scientist is not only encouraged by the film *Flubber* but it is also perpetuated by many popular science fiction films that portray scientists as being out of touch with reality and living in their own worlds. Scientists are frequently depicted in their basement laboratories, working all through the night, making bubbly, explosive solutions by mixing chemicals in complex scientific equipment. This stereotypical view of scientists is the one that is commonly revealed in children's drawings (Jane & Gipps, 2006).

A literature review of studies of images of science and scientists in popular culture reveals several important features. Firstly the image of the scientist is generally a negative one. Scientists are usually portrayed as mad or so dedicated to their work that they are completely insensitive to their colleagues and families. Secondly, the image of science portrayed in popular culture does not reflect the actual way in which science progresses. The slow and painstaking process in which scientific knowledge is gradually built up is rarely shown. Instead the 'gee whiz' syndrome is present.

In her book, *From Faust to Strangelove: Representations of the scientist in Western literature,* Roslynn Haynes explores the many ways in which scientists have been represented in literature over time, beginning with the late Middle Ages. “The popular image of the scientist changed from that of either a stupid or a sinister character to that of a highly respected man of genius representing the highest attainments of reason” (Haynes,1994:50). She proposes the following recurrent stereotypical representations of scientists in Western literature:

- *Alchemist*, who appears at critical times obsessed or maniacal scientist, most recently as the genetic engineering biologist. (e.g. lone wolf scientist Victor Frankenstein, in Mary Shelley's *Frankenstein*)
- S*tupid asocial virtuoso*, who is out of touch with the real world, is both comic and sinister, the absent-minded professor. (e.g. astronomer Merrival, in Mary Shelley's *The Last Man,* and the professor in *Flubber*)
- *Heroic adventurer,* in the physical or intellectual world, emerges at times of scientific optimism, but often a neo-imperialist. (e.g. heroic physician Tom

Thurnall, in Charles Kingsley's *Two Years Ago*, and benevolent scientist in George Meredith's *Melampus*).

- *Scientist as helpless*, lost control over his discovery or over the direction of its implementation. (e.g. Victor Frankenstein's isolation deprived him of a sense of social morality)
- *Scientist as idealist or world saviour*, an acceptable scientist who sometimes holds out the possibility of a scientifically sustained utopia, but who often is engaged in conflict with a technology-based system that fails to provide for individual human values. (e.g. as seen in the film *AI*)

Previous research studies of students' and pre-service teachers' perceptions of scientists

Consistent with cultural-historical theory, this section begins with a description of what is currently happening in science education, while also taking into account the consequences of the past that have given rise to the stereotypical views of scientists that are so popular with students. In the literature, the first to report on research that explored students' perceptions of scientists were Mead and Metrax (1957). Three decades later, science educators identified the characteristics of stereotypical images of scientists as depicted in students' drawings (Schibeci & Sorensen, 1983). Since then the 'Draw-A-Scientist' Test (DAST) (Chambers, 1983) has been used extensively as a tool for researchers to explore students' views about scientists. Students' drawings are coded according to the following DAST indicators of a stereotypical image of a scientist (Chambers, 1983; Purbrick, 1997):

- laboratory coat;
- spectacles or eyeglasses;
- facial hair (beards, moustaches, very long sideburns);
- laboratory equipment (bubbly solutions, scientific instruments);
- books and filing cabinets;
- technological products of science; and
- captions (formulae, eureka!).

A further development generated the 'Draw-A-Scientist Test Checklist' (DAST-C) as a reliable and efficient format for analysing students' drawings of scientists (Finson, Beaver & Cramond, 1995). This checklist provides quantifiable scores for drawings that facilitate comparative data analysis. In a study undertaken in Indianapolis the DAST-C was used to analyse more than 1,500 K-8 students' drawings (Barman, 1999). Results showed that most scientists were depicted as white males, which supported previous studies (Chambers, 1983; Fort & Varney, 1989; Finson et al., 1995; Huber & Barton, 1995). More recent research shows that the stereotypical images influence how students perceive science, and that negative images of scientists can affect the choice of careers by minorities in general and females in particular (Finson, 2003).

An examination of studies of student teachers (McDuffie, 2001; Matkins, 1996; Rahm & Charbonneau, 1997; Rosenthal, 1993) revealed that all "confirm the prevalence of the scientist stereotype" (Schibeci, 2006:13). In Germany Markic, Valanides and Eilks (2005) evaluated 104 science student teachers' conceptions using a modified version of the 'Draw a Science Teacher Teaching-Checklist' (DASTT-C). They found that secondary chemistry and physics student teachers held conventional and teacher-centred views about science teaching and learning. In contrast, biology student teachers and primary science student teachers had more open, student-centred views on teaching (Thomas, Pederson & Finson, 2001).

Although DAST is a useful research tool to probe students' images of scientists, Schibeci (2006) favours other procedures such as interviews and 'Interviews-About-Instances' (White & Gunstone, 1992), because interviews facilitate in-depth probing of students' views. Probing students' views is an important component of teaching based on the view of learning called constructivism. Constructivism is the view of learning whereby individuals actively generate meaning from experience.

Science teaching based on constructivism

For more than two decades the science education academy has focussed on different constructivist approaches to teaching science. The majority of science educators still focus on the individual learner acquiring knowledge or concepts, and advocate a conceptual change approach to teaching science. There is longstanding research that demonstrates the difficulties that primary and early childhood teachers face when teaching science in schools and centres (Loughran, Mulhall & Berry, 2004; Mulholland & Wallace, 2005; Sadler & Zeidler, 2004; Shallcross, Spink Stephenson & Warwick, 2002). Masters (2007:16) calls for a new formula in science teaching:

"High quality, passionate teachers are needed to head off a looming crisis for science in Australia. ... The need for science literacy has never been greater... but surveys of students consistently show that they cannot see the relevance of school science to their lives" (p. 16). Constructivism has its limitations and we identify the need for a shift to research from a cultural-historical perspective that challenges the notion of conceptual change (see Lemke, 2001).

Cultural-historical perspective: transformation through participation

Research on the transformation of understandings through participation (Rogoff, 1995) has important implications for science teaching and learning. From a cultural-historical perspective, three planes of participation, the personal, interpersonal and cultural or institutional (Rogoff, 1998) are applicable to any activity, including practical activity in science. These different planes can be likened to lenses that enable the focus to be on individuals, or groups of people as they participate in cultural activities such as science.

Using personal, interpersonal and community/institutional planes of analysis involves focusing on one plane, but still using background information from the other planes, as if with different lenses. (Rogoff, 1998:688)

The interpersonal lens enables the focus to be on the relationships that support or structure the shared understanding. When researchers change their focus, the interactions are analysed without prioritising any particular plane, nor isolating it from the other planes. "Foregrounding one plane of focus still involves the participation of the backgrounded planes of focus" (Rogoff 1995:140). These planes of participation are inseparable, yet mutual, and show an individual's participation or involvement in a cultural context.

A focus on the 'personal plane of participation' allows researchers to concentrate on the role of the individual and identify how that individual changes through involvement in a particular activity. Shifting focus to the 'interpersonal plane of participation' enables researchers to identify how individuals communicate with one another as they engage in shared endeavours. Highlighting the 'cultural or institutional plane of participation' reveals how people use cultural tools as they participate with others in culturally organized activities. These activities are often determined by institutional practices with inherent cultural values. Rogoff's (1998) three foci of analysis allows researchers to go beyond researching simply the individual's framework for thinking about science to concentrating on how the relations between the individual and others within their community shape what they pay attention to. What a community values, including how a community positions its scientists - whether by popular press or otherwise - has a lasting effect upon children and young people (see Roth & Lee 2004).

Cultural-historical theory provides a useful framework for understanding teaching and learning because it moves the unit of analysis beyond the individual and examines both the relations between people, culture, community and institutions, such as schools. Hedegaard and Chaiklin (2005) have written extensively on the 'double move approach to instruction', where the subject-matter concepts are integrated with children's everyday knowledge by using theoretical knowledge as the frame for school activities. The double move approach stems from Davydov's (1988) developmental teaching-learning approach. The theoretical knowledge is a tool for linking local and personal everyday knowledge with the core concepts. The purpose of the double move is to enable a person to acquire theoretical knowledge (by integrating local knowledge with core concepts) and then use it in the person's local practice. In the double move approach the teaching situation is organized in such a way that the content of local knowledge is highly valued and used to develop theoretical knowledge. Children's understandings are enhanced when their personal everyday knowledge of community and home practice, becomes integrated with subject-matter knowledge. The children's enriched understanding is helpful to their understanding of everyday local practice. When the unit of analysis goes beyond the individual and examines the social, cultural and institutional dimensions, it becomes possible to see how community views on the nature of science and being a scientist must be highlighted when researching science education.

Research questions and study design

The study investigated the following research questions.

- What do children's drawings and comments reveal about their views of science and scientists?

- How does school-based small group teaching influence these views?

The context of the study

The study took place in the context of a one semester, second-year Education unit entitled 'Curriculum Studies Primary Science', which was organised as school-based in three primary schools on the Mornington Peninsula, 65 kilometres south east of Melbourne, Australia. Pre-service teachers enrolled in the unit attended the schools for eight weeks and taught one-hour lessons to a small group of children.

Every time they visited the schools, the pre-service teachers participated in the Curriculum Studies program that consisted of a one-hour tutorial involving hands-on activities, half an hour for preparation (and coffee), an hour teaching the children and a half-hour debriefing session. Initially tutorials started as hands-on activities that could be implemented in the classroom. As the semester progressed, the tutorials focussed on the different teaching approaches and their theoretical underpinnings. Beverley (the first author) was the lecturer in charge of the unit and taught two tutorial groups at one school, while the science specialists at two schools taught one tutorial each. The science content taught varied from school to school, but most tutors included sessions on 'What is a science?, magnetism and electricity, animals and plants, floating and sinking, and chemical change. The pre-service teachers generated PowerPoint presentations consisting of descriptions of what occurred in the classroom, observations of the children's involvement, and reflections on what they and the children had learnt. These presentations included digital photographs and short video clips that were taken with written permission from the children's parents or guardians. Children whose parents or guardians refused permission were not photographed.

John (the third author) helped the pre-service teachers with the science content, organised equipment and materials, and administered WebCT that was widely used for communication between the pre-service teachers during the week. John also took photographs of them interacting with their small group of children and recorded verbatim comments during the follow up debriefing sessions. Triangulation of data was achieved by having two researchers collect data in multiple ways. Marilyn (the second author) documented the reciprocal interactions between the pre-service teachers and children in the form of field notes, digital photographs and video-clips.

The participants

Timetable considerations and the class teachers who wanted to be associated with the program, meant that children in Preps/Year 1 or Years 5/6 participated in the school-based program. The topics covered were the same for each level, although the pre-service teachers soon found out that different grade levels called for particular materials and teaching strategies.

Prior to this unit most of the 120 Primary and Early Childhood pre-service teachers had experienced very little contact with science since middle secondary school, and some had quite a negative view of science as a subject. In the first week in the primary school they were uncertain, and concerned that the children would see them as having little knowledge of the subject matter. For their first couple of lessons, most repeated the hands-on activities they had carried out in the tutorials, but gradually they diverged following their own and the children's interests. Initially, we supplied all the materials and equipment, but as the semester progressed the pre-service teachers gathered the materials they needed for their small group. Some pre-service teachers planned and brought everything they required, while others allowed the children's questions to be the sole determinant of how things progressed. While each pre-service teacher was allocated four or five children and could operate individually, most decided to work in pairs and some organised activities on a whole-class basis.

The pre-service teachers were teaching science by doing it, and asking the children questions, such as 'What do you want to know about?', 'What would happen if ...?', 'This happened - why?' and 'How can we test that idea?' A range of activities including practical experiments, making things, worksheets, book research, reading stories, discussions, games, excursions to the playground were all used. The preparation time following the tutorial included discussion and exchange of ideas. In this way a community of learners naturally developed. WebCT facilitated frequent communication between the pre-service teachers when they were not at the school, and also between those at different schools who may not see each other during the week. 'I intend to do ..., what do you think?' 'Why not try ...?' 'I tried ..., it was OK but next time I would ...' 'If I bring these items, will you bring the rest?' 'Does anyone know of any good references on ...?' 'I found this great website on ....'

Data collection and method of analysis

In their first science lesson teaching their small group, most pre-service teachers encouraged the children to 'draw a scientist or a group of scientists' and then to talk about their drawings. The children's drawings and comments about science and scientists became the data for analysis. Data were also collected in the form of the pre-service teachers' reflections about their group's thinking in science. Ethical considerations were taken into account concerning the pre-service teachers' involvement in data collection. One aim of the Education course is to produce initial teachers who are capable of carrying out research on their own practice. To achieve this aim, where possible, units provide opportunities for pre-service teachers to participate in data gathering techniques first hand. The pre-service teachers willingly took on the role of co-researchers in this study. Moreover, as collaborators in the research process, they became more aware of the need to listen closely to what the children had to say, and to recognise the value of pedagogical documentation.

As mentioned above, constructivism has been the view of learning that to date has dominated how research is framed, how data are analysed, and how findings are used to inform curriculum, policy and pedagogy in the science education community. A cultural-historical perspective offers a new theoretical orientation, new ways of thinking about research, and new possibilities in science education. As researchers we found Rogoff's (1998) work useful for determining the unit of analysis in this study and for framing the theoretical drivers that shaped that analysis. Rogoff's three planes of participation - the personal, interpersonal and cultural/institutional - were applied to the teaching and learning that occurred in the small groups.

In the present study, the personal plane of participation indicated how the individual child changed through involvement in the small group science activities. The individual child's role was highlighted, while at the same time the interpersonal and community involvement faded into the background. The interpersonal lens focused attention on the shared understandings that developed as the children engaged with the pre-service teachers and other members of their small group. The interpersonal plane of participation highlighted how the children communicated with their peers. Engagement and shared endeavours were central in this plane. The cultural/institutional lens focused on specific community constructions of science, and the cultural tools that were used. By changing the focus to another plane the interactions were analysed without prioritising or isolating any particular plane. When taken together, these inseparable planes of cultural participation reveal an individual child's participation in the particular cultural context of the science classroom.

Data analysis: children's drawings of scientists and their comments about science

Most children's drawings showed the stereotypical 'scientist'; white lab coat, with beakers and test tubes, working in a laboratory and carrying out experiments. Some children said that scientists have useful skills and make lots of money. The majority thought scientists were mostly males, but some recognised that there are female scientists too. Most drawings showed stereotypical images of scientists as looking weird, bad and mad. A representative example is Chloe's drawing (Figure 1) and comments (Figure 2).

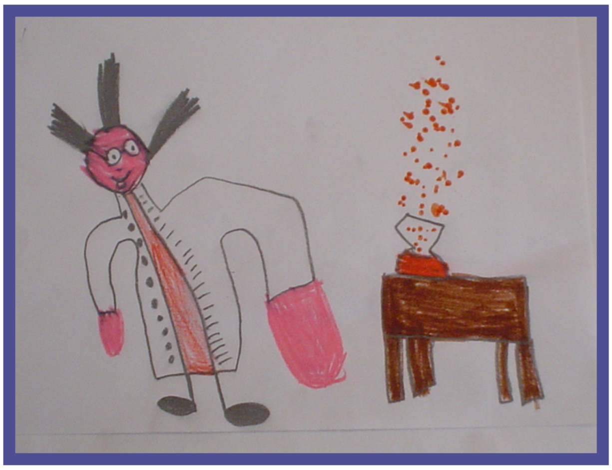

Figure 1. *Chloe's drawing of a mad scientist (Fleer, Jane & Hardy, 2007:7)*

When asked to talk about her drawing: Chloe "scientists make stuff like potions." When asked what these potions are used: Chloe "They turned a man into a lama and then he needed another potion to turn him back into a person." When asked why she thought that: Chloe "I saw it on The Emperors New Groove!"

Figure 2. *Chloe's comments about her drawing of a scientist*

Children in Years 5 and 6 had more developed ideas (Figure 3).

Can scientists be fashion designers?
Scientists invent things. They explode things too.
Scientists blow things up! KABANG! BOOM! SHEBANG!
My sister Emile is a scientist. She has a ring in her nose and through her lip!
Scientists learn about things like cells and chemicals.
Investigating things, inventing things, exploding things. That's what scientists do.

Figure 3. *Stereotyping scientists by Years 5 and 6 children (Fleer, Jane & Hardy, 2007:9)*

The influence of the media

In Figure 2 above, Chloe's last comment "I saw it on The Emporer's Groove!" provides evidence of the media as an influencing factor. The following children's comments indicate the influence of television.

"On *Survivor* they use their T-Shirts to make water cleaner, it was on TV the other night".
"They bent water like this on *Wicked Science* once, but that was ages ago".

One pre-service teacher reflected:

> Towards the end of our time with the group, a new show started on TV called *Braniac,* a show that focuses mostly on explosions, silly and dangerous experiments. They would talk about it during our sessions and it definitely influenced their view of science. This show made science seem more cool because they did crazy and funny experiments.

Children as rudimentary scientists

By the end of the science program some children realised that they themselves were scientists (Figure 4).

WE ARE SCIENTISTS!
✓ We worked as a group!
✓ We explored!
✓ We made theories!
✓ We researched!
✓ We discovered!
✓ We had fun!

Figure 4. *Children working in a scientific way*

Consistent with these views, one pre-service teacher reflected:

> Children benefit a great deal more when the lesson and the topic is interesting, motivating and where they can actually get involved themselves. This enables them to discover and construct their own meanings and in a sense **become mini-scientists themselves**. I would like to continue using a hands-on/discovery approach when teaching science as it gives the power to the children and sees them as the pivotal part of science teaching. (our emphasis)

Another pre-service teacher planned to challenge the children's stereotypical views of scientists and science as the following reflection shows:

> The students had a fantastic time conducting the food experiments. They were excited because the experiments belonged to them: it was their ideas that formed this lesson. I wanted to show students that science wasn't "hard work done by those geeky guys in white coats and glasses". I wanted to show them science is a part of our daily lives and a subject that everyone can be actively involved in. I know I succeeded at this task when a student approached me and declared: "I thought that Science was just Chemistry stuff. This is so fun! **I want to be a scientist** when I finish school". (our emphasis)

Evidence of changes in the children's views

Table 1 contains data that show children's views before and after the small group teaching experiences. There is evidence of changes in their views.

Table 1. *Children's views of science and scientists*

Children's 'initial' thoughts about science and scientists	**Children's thoughts about science and scientists 'after' the group teaching**
Gp 1. Science is:	Science is:
experiments, fun, making things, putting things together, science works, learning, blowing things up, fun	finding out how air works, trying different lots of things, digging up fossils, creating your own experiments
Gp 2. Science is:	Science is:
about making things explode (J)	about exploring the things around us (J)
doing interesting stuff (Je)	about bugs and things (Je)
making volcanoes (S)	doing experiments (S)
boring stuff (L)	trying my hardest and experimenting with different things (L)
boring (Ja)	learning electricity (Ja)
making medicines (D)	fun and doing lots of different experiments (D)
blowing things up and inventing things (Jo)	learning about different stuff (Jo)
Gp 3. Science is:	Science is:
static electricity, heat, food (J)	chemical reactions. I don't like some scientists. We did lots of stuff (J)
chemicals, light (L)	great, lots of things, **I am a scientist** (L)
food (N)	can be fun. Is not just about food (N)
chemicals, solar system, electricity, experiments, magnets, energy (Je)	physical reactions. It is really fun. It's about experimenting. Scientists rock! (Je)

Gp 4. Scientists are:	Science is:
nerds, freaks, dissect things, destroy	the best, cool

Gp 5. Science is:	
mixing chemicals and blowing things up (R)	Science is fun! Now I know about chemical reactions (R)
growing plants (Sa)	I like Science. I can do it (Sa)
chemicals, liquids and labs (E)	Everything we do is science (E)
doing experiments, discovering new things (S)	Science is everything (S)
testing all different things (chemical reactions) (T)	Lighting a light bulb with a battery is science (T)
making volcanoes (K)	There is science when we make sherbert (K)

One pre-service teacher reflected on the effect of the students' hands-on exploration with materials.

> We are able to see how the students' thoughts before and after changed because of the results. Usually one or two students expected the outcome to occur but often there was some debating prior to the experiment that actually led to the students being more interested in the results.
>
> I believe the students learned from our experiments and they were always interested in what we would be doing each week. Their beliefs about science and science stereotypes were challenged, but in a way that they found fun and you can tell from their responses that are occasionally joking yet contain some serious thought shifts. I found that they were able to solidly back up their own theories.

Figure 4 above shows that by the end of the semester of hands-on activities with the pre-service teachers, some children thought they were working in a scientific way. These children value working in groups, researching, exploring, discovering and theorising, which incorporate cognitive and affective dimensions and reveal positive attitudes towards science. The pre-service teachers were doing science with the children and in the process changing their own ideas and that of the children. Fleer, Jane and Hardy (2007) call this 'reciprocal teaching'.

> Reciprocal teaching is about the children 'teaching teachers' about their everyday world and embedded everyday concepts, and 'teachers teaching' children about scientific concepts to transform the children's everyday world. In order to achieve this, a high level of intersubjectivity between children and teachers is needed. (Fleer, Jane & Hardy, 2007:189)

Implications of the study and conclusion

There has been considerable research about the difficulties primary and early childhood teachers face when teaching science (e.g. Garbett, 2003; Goodrum, Hackling & Rennie, 2001), researchers have neglected to examine how pre-service teachers actually engage with the content and pedagogy for science teaching (see Appleton, 2006). This article focused on a study that explored children's pre-instructional views of science and scientists, and their views following a teaching sequence by pre-service teachers. The format of the school-based unit encouraged the pre-service teachers to plan and implement hands-on, discovery and reciprocal approaches when teaching science. They were able to apply educational theory immediately to a classroom situation.

Implications of the study point to a pro-active model for science teaching that encompasses reciprocity, with teachers actively listening to the children to identify their thinking about scientific phenomena, while the children engage in authentic practical activity. The study, designed from a cultural-historical perspective, found that when the individual child is valued in a communal context, and engages in hands-on science activities that are relevant and authentic, children's views about scientists are challenged as they begin to see themselves as rudimentary scientists. The data collected included children's drawings and comments, and pre-service teachers' reflections. Data analysis suggests that the teaching sequence of hands-on activities provided by the pre-service teachers encouraged change in children's views of scientists.

Acknowledgements

We are appreciative of the support given to the science program by the school staff. We thank the children and Monash University Education students for their willing participation.

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