Towards Building Science Teachers' Understandings of Contemporary Science Practices

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Abstract

Faculties of Education and Science at Monash University have designed a Masters unit to assist pre-service and in-service science teachers in exploring the practices of contemporary science and examine how varied understandings can influence science communication. Teachers are encouraged to explore their current understandings of the Nature of Science (NoS) and to contrast their views with those known to be widely held by society (Cobern & Loving, 1998). Teachers are challenged to provide insights into their thinking relating to the NoS. In order to build understandings of contemporary science practice each teacher shadows a research scientist and engages them in conversations intended to explore the scientists' views of NoS and practice. Findings suggest that teachers were initially uncomfortable with the challenge to express ideas relating to their NoS and were also surprised how diverse the views of NoS can be among teachers, scientists and their peers, and that these views can directly impact ways of communicating contemporary science practice.

Keywords: scientific practices; the nature of science, science education, STEM workforce.

Introduction

There has been a worldwide call for greater education in science, technology, engineering and math (STEM) if we are to meet the workforce needs of the 21st century. Yet at the same time, there are more STEM students graduating while jobs in both developed and emerging countries are going unfilled, creating somewhat of a paradox (New York Academy of Sciences, 2014).

In Australia and internationally there is acknowledgement of decreased participation rates[1] across the secondary and tertiary sectors of students engaging in the study of science, mathematics technology and engineering (Kennedy, Lyons & Quinn, 2014; Mack & Wilson, 2014; Smith & Gorard, 2011; Charette, 2013). These decreased participation rates are often likened to a "leaking pipeline." However, this metaphor is misleading (Cannady, Greenwald & Harris, 2014) as it:

- fails to describe the experiences for about half of those who become scientists or engineers,
- masks meaningful differences in trajectories, particularly in subfields, and
- informs policies in ways that do not account for diversifying or increasing the size of the STEM workforce.

Schools and universities are often "blamed" for not educating enough STEM students, but this does not really capture the complexity of the STEM supply and demand issue. There are largely four main reasons to account for this somewhat paradoxical situation:

1. A shortage of graduates with soft skills. It is often difficult for graduates to apply the concepts they have learned to challenges in the workplace and their work is made more difficult as they often have had little opportunity to develop soft skills in communication, critical thinking and teamwork, which are essential attributes for successful employment. For example, Indian employers report serious shortages in the engineering workforce due to graduates lacking interpersonal and critical thinking skills (Bolm & Saeki, 2011).
2. Lack of qualified technicians. In many countries the education system in not sufficiently aligned with industry in order to develop student attributes that meet employer needs. Graduates are often over-qualified for the positions that need filling. For example in USA manufacturing industries, 67% of manufacturing employers report they are unable to fill mid-level technical positions (Manufacturing Institute & Deloittes, 2011).
3. Loss of high-skilled workers. While many countries are producing STEM graduates, the opportunities for graduates in their own countries can often be limited – resulting in a "brain drain". This phenomenon is present in many countries both developed, such as Australia and emerging such as the Caribbean (UNDESA & OECD, 2013).
4. Untapped pools of Talent. Women, rural populations, minority ethnic groups, lower socio-economic groups and other marginalized groups are acutely under-represented in STEM fields in most developed and developing countries (UNESCO, 2014; Office of Chief Scientist, 2016).

[1] Participation rates have been declining; however, the relative numbers of students studying these subjects, particularly in secondary schools, has remained similar even though more students are completing secondary schooling.

These four challenges together create a self-reinforcing global cycle that is difficult to break and as the loss of talent in STEM diminishes, the pool of capable teachers and mentors who can assist students in developing the necessary skills (including soft skills) for future employees in technology and science-based industries diminishes as well. Similarly, poor matches between educational pathways and employment opportunities discourage and/or prevent STEM graduates filling the available STEM jobs. Solutions will need to extend beyond the simple encouragement of more students seeking STEM degrees as this will not guarantee that they leave their education with the needed contemporary skills and capabilities. Governments, schools and industry will need to work together more closely in creating a robust "STEM ecosystem" (New York Academy of Sciences, 2014) as needed if such a STEM paradox is to be overcome.

The essential practices required to build a strong STEM ecosystem are (a) government policies that incentivize companies to invest in innovation and scientific research and development to create promising job opportunities for STEM graduates, (b) a strong education system that combines learning with real-world experiences in order to promote both technical and personal professional skills, and (c) a STEM culture embedded in the population in ways that highlight the importance of developing an understanding of opportunities that exist within STEM.

This paper deliberately focuses on Australia's response to building a strong STEM ecosystem, which would be characterized by strength in all three practices above. Some countries such as South Korea have such strengths in all areas), while many have strength in only one or two areas. Australia has some strong initiatives in each area, but still has much to do (as many other developed countries) to build a strong STEM ecosystem. In this paper we will be focusing on an initiative of the Australian Government that firmly exists within the second set of these practices; building understanding of real world contemporary science practices in our future and current science teachers.

Literature Review – Background

As reported by the Australian Office of the Chief Scientist (Office of Chief Scientist, 2014), there is growing acceptance by industry employers that scientific and mathematical competencies are essential for productive participation in a growing competitive knowledge-based economy. This report stated that 75% of the fastest growing occupations required science, technology, engineering and mathematics skills and knowledge in order to be internationally competitive. Twenty-first century workplaces will increasingly rely on employees having skills in digital communication, information technology and knowledge of mathematical competencies essential for analytical and financial modelling. Longitudinal results from the Programme for International Student Assessment, PISA (Australian Council of Educational Research (ACER), 2001; Thomson, De Bortoli, & Buckley, 2013) showed that Australian students' performance in Mathematics and Science literacy experienced a decline between 2000 and 2012, equivalent to a reduction of more than half a year of schooling. Likewise, in a review of outcomes of school education in Australia by the ACER (Ainley & Gebhardt, 2013), a comparative analysis of 2012 PISA and NAPLAN data shows that student performance is weakening among both low and high achieving students.

A more recent study (Kennedy, Lyons, & Quinn, 2014) compared subject enrolments of year 12 students in New South Wales between 1992 and 2012. They found that although there was an increase in participation by more than 30,800 students in 2012, there were 8,000 fewer students studying physics, 4,000 fewer studying chemistry and 12,000 fewer studying biology compared with 1992. These reductions are similarly reflected in other states in Australia. Earth Science, the least popular science subject was the only science course analyzed where participation rates were shown to increase and this interest was attributed to the global resources boom active at this time. The percentage of students studying advanced and intermediate mathematics also declined over a similar period but the proportion of students selecting entry-level mathematics grew by 60 percent. The number of students (Mack & Wilson, 2014) shunning both mathematics and science has also risen, from 2.1 percent (male) and 5.4 percent (female) in 2001 to 5.9 percent (male) and 14.6 percent (female) in 2014. Similar trends have also been observed for Information Technology participation in schools (Ainley, Kos & Nicolas, 2008).

There has been wide speculation as to the reasons underpinning this decline in student STEM engagement and although this is seen more or less as a worldwide trend (Langen & Dekkers, 2005; Henriksen, Dillon & Ryder, 2015) little research has been able to authoritatively identify the key contributors in effect across international contexts. Australian sector experts identify a range of possible reasons for this decline. These include a deficit of enthusiastic, confident, and competent teachers in the early years to an Australian secondary system which offers too many subject choices in the senior years. Others lament a local tertiary entrance scheme which consequently rewards the brightest of our final year secondary students for selecting less difficult subjects in which they have greater opportunities to achieve outstanding results to maximize their University admission scores. Less attention appears to be paid to the possible combined impact caused by higher education fee increases, diminishing employment opportunities and declining industry incentives caused by the more widespread use of fixed contracts and increasing downward pressures on salaries within the industry.

In an interview conducted by John Burgher (Burgher, 2014) with Professor Iwona Miliszewska, Australian Council, Deans of Information and Communication Technologies, suggested a comprehensive, multi-pronged approach encompassing many ideas similar to those proposed by other industry experts, to encourage greater student interest in STEM engagement by:

- Enhancement of compulsory STEM education through a major revision to the national curriculum that resolves to increase the study hours and content of STEM classes in both primary and secondary schools. The goal of this initiative would be to improve the quality of basic STEM education nationwide, generating and stimulating interest in scientific topics and thus creating a broad support base for STEM in Australian society.
- Introduction of programs to nurture and train the best and brightest STEM talent by enhancing “elite” education; such programs would lay the foundation for a STEM “elite track” from secondary to tertiary levels of education.
- Facilitation of university-to-career transitions by supporting job placement of graduate students and post-doctoral researchers who complete degrees in STEM fields.
- Specifically addressing the under-representation of women in STEM education and careers by launching targeted initiatives supported through both public and corporate sector funding.

In acknowledgement of this deepening problem the Australian Government announced its *Students First-Restoring the focus on STEM in schools initiative* (Australian Government, 2015) that committed 12 million dollars to restore the focus on and increase student uptake of science, technology, engineering, and mathematics subjects in primary and secondary schools across the nation. It consisted of four key initiatives:

- Providing innovative mathematics curriculum resources for primary and secondary school students, focusing on inquiry-led teaching.
- Supporting the introduction of computer coding across different year levels in Australian schools leading to greater exposure to logical and computational thinking.
- An innovative approach to education based on the successful "Pathways in Technology Early College High School" program originating in the United States of America, and
- The introduction of summer schools for STEM students, to increase the number of girls and disadvantaged students (including Indigenous students and those from regional and remote areas) engaging with STEM.

The initiative also focused on the preparation of prospective STEM teachers through a number of targeted learning research grants. One of these grants was the ReMSTEP project.

The ReMSTEP Project

As part of the national initiative, the Australian Government Office of Learning and Teaching (OLT) provided funding in 2014 for two years to four collaborating universities. The University of Melbourne, Deakin University, La Trobe University, and Monash University were charged with exploring how pre-service teacher (PST) education programs could be enhanced in ways to better provide PSTs with greater competence and confidence in their teaching of science and mathematics. In particular, the focus was on examining productive ways of integrating the specialist knowledge of practicing scientists, researchers, and STEM specialists into the school curriculum and teacher classroom practice in order to create greater engagement and subject relevance for students. The project entitled Reconceptualising Mathematics and Science Teaching Education Programs, (see www.remstep.org) shares the vision of the Chief Scientist of Australia (Office of Chief Scientist, 2014). This vision advocates that learning and teaching STEM competencies should introduce students to aspects of contemporary science, technology, engineering, and mathematics practices in ways that students and teachers find exciting and socially relevant, rather than following a curriculum that represents STEM subjects as apparently divorced from any real-world applications or social contexts.

Monash University's involvement in the ReMSTEP project offers exciting opportunities as it involves the development and researching of new PST programs to better address the social relevance of science, technology and mathematics and importantly the sharing of these research findings across all four universities. This paper explores just one of these new initiatives resulting from collaboration between the Faculties of Education and Science at Monash University. The Monash ReMSTEP project team was keen to develop new opportunities for PSTs to experience and better understand many of the contemporary practices of science and mathematics used widely across a range of industry sectors. The assumption underpinning this initiative was that teachers who are more informed and better able to discuss these practices with greater confidence should be more capable of achieving greater classroom engagement and improved student interest in the future study of STEM subjects. The new Master of Teaching unit (equivalent to 288 hours of study) was devised with a number of key objectives consistent with the ReMSTEP project and incorporated successful reflective pedagogical approaches informed by past evidence-based science education research undertaken by the Faculty of Education.

Unit Objectives

Three key unit objectives were identified to encourage PSTs:

- Understand how sciences (including mathematics) knowledge, processes and communication shift over time through the influence of social and technological change.
- Explore the diverse and changing understandings of the Nature of Science (NoS) while challenging participants to re-conceptualize and articulate their own personal contemporary view.
- Investigate first hand contemporary practices of science and examine how the creation of new knowledge has significantly changed to become more inter-/multi- and trans-disciplinary, e.g. nanoscience, and bio-informatics.

Each of these is briefly discussed. The first objective underpinning the unit focuses on how science knowledge changes over time. Much of the knowledge and practices of science and mathematics are tentative and undergo constant reappraisal and update. Some ideas prove to be more enduring than others, however all ideas remain open to question. The creation of new technology can often have substantive impacts on how new knowledge is generated and in turn, this can influence the directions of subsequent technology development and applications. The idea that science knowledge and contemporary practices are tentative and changing is not widely explored in science or mathematics classes in secondary schools where content is often conveniently delivered as definitive and enduring.

Present textbooks are more likely to be revised to accommodate changing government curriculum initiatives rather than contemporary changes in science knowledge, such as new or revised understandings or the impact of advances in technology. For example, the continuing debate over the classification of Pluto as a planet and what should constitute a planet in our solar system may be seen by some as revealing an indecisiveness or a weakness of enduring knowledge and authority in science. However the debate by planetary scientists over the need for change of such a historical classification system provides insights into the dynamic nature of the sciences and the need for the sciences to constantly reassess and accommodate changing understandings based on the acquisition of new evidence. To ignore such instances of debate and review is to ignore a critical aspect of how sciences are undertaken and that all scientific knowledge should remain open to question and revision.

The second objective identifies that contemporary practices of science and mathematics and the new knowledge arising from such practices, has largely now changed to become more inter-/multi- and trans-disciplinary in nature. Increasingly more science research is now being undertaken at the fringes between the traditional subject disciplines. This requires researchers to have broad understandings across a number of what were once seen to be independent fields of specialization. Emerging areas such as nano-science, nanotechnology, bio-informatics, regenerative and imaging technology, require complex understandings of multiple disciplines. However, despite this mix of traditional discipline areas, the key processes by which sciences are undertaken and the overarching objectives remain equally applicable. This unit aims to make the processes of sciences and their associated skills more explicit for PSTs and emphasizes the importance for teachers to also make these explicit to their students as a part of their regular classroom practice. The unit seeks to identify the importance of science, mathematics and associated technologies as “a way of knowing and exploring our world” where cross-discipline understandings have the potential for convergent investigation to generate richer understandings and reveal unseen complexity and interdependence.

Interviewing Scientists about their Practice

Although it is possible that some PSTs undertaking the unit may have strong backgrounds in the sciences, engineering or mathematical studies, including research backgrounds (or even PhDs) in related sciences or engineering fields, this is not typically the case. In addition, many PST of early years students often have more limited science and mathematical backgrounds. Given this diverse mix of science experience amongst the PST cohort it was felt essential that all PSTs should undertake a visit to a contemporary research facility where they can meet with and interview practicing scientists. The intention of this visit is to provide the PST's with a face-to- face experience in which they can chat with scientists to explore the nature of their work and familiarize themselves with the operation and practices of a contemporary research facility. The PSTs are then encouraged to share their reflective insights gained from the visits in brief video reports suitable for sharing with their peers in workshop discussions.

Monash University, as a research intensive university, is fortunate that it has a large number of world class “Centers of Excellence” and more than 20 expert research scientists operating across these have agreed to meet individually with a PST for several hours. In addition, a number of expert scientists from the Melbourne Museum (Australia) in specialist areas of entomology, paleontology, and plant physiology have also agreed to be involved in the program. In almost all cases the scientists have been approached to be involved in this program because they are engaged in research areas which help to demonstrate the highly interdisciplinary nature of contemporary research and they have a demonstrated track record for seeking to actively communicate their understandings of science to a wide range of audiences. Prior to the PSTs visiting the research centers the purpose of the visit is discussed and scaffolded in the unit workshops to make the intentions explicit and to assist the PSTs in constructing relevant interview questions that will explore the scientists understandings of the Nature of Science (NoS) and the purpose and range of audiences that they routinely communicate with. This approach is intended to assist the PSTs to maximize the learning benefits achieved from such a relatively brief visit to an authentic research setting.

Five Areas of Science Cognitive Engagement

Examining the effective communication of science, mathematics and technology is periodically revisited throughout the unit in ways that assist in reinforcing the importance for teachers to embed the investigation of STEM knowledge in a social context. A schema developed by Corrigan (2015), attempts to assist the PSTs in their analysis of the methods and intentions of the different types of science communication engaged in by contemporary scientists. This approach is seen as innovative as it tries to assists the PSTs to distinguish between the broad areas of complex cognitive engagement needed for effective communication with different audiences for different purposes. The schema attempts to identify 5 areas of science cognitive engagement that scientists, technologists and researchers are likely to engage with:

1) **General Public Engagement** – this is probably the most basic level of communication, however even though the sophistication of the science knowledge exchanged is likely to be quite elementary it does not imply that it is not without challenge. Looking to effectively communicate insights into big ideas or complex processes using appropriate metaphors or

analogies is a creative and demanding task which confronts many educators on a day to day basis. Predictably not all scientists are skilled at communicating with the general public which make those that are, such as Tim Flannery, Richard Dawkins and Brian Cox highly sought after by both the mainstream media and the general public.

2) **Informed Engagement** – This describes engagement by those who are conversant with a scientific field or discipline. They are informed and seek opportunities to share and improve their knowledge and understanding amongst competent peers with similar interests or expertise. This form of engagement is practiced widely by amateur interest groups, student societies and professional institutes and associations, e.g. amateur astronomical societies, soil science engineers, the Australian Society for Microbiology, the Royal Australian Chemical Institute, and the Australian Academy of Science.

3) **Applied Engagement** – This describes a broad engagement by scientists, engineers, technical designers and science communicators who apply current scientific knowledge to develop real world applications of technology or to share insights into fundamental processes of science. Their interests may include fields such as; engineering, medical imaging, robotics, polymer science or nanotechnology. They use the knowledge of science and its processes, e.g. experimental design, analysis of data and scientific modelling to test and improve technology and its applications.

4) **Focused Engagement** – This includes engagement which deals with the more routine practicalities of communication practices within and between scientific or industry research centers. Examples could include system approaches for regular reporting on project challenges and achievements to project personal, routine laboratory meetings, initiatives exploring workflow or communication practices and team reviews of technical protocols. It could also include the reporting of project mile stones to Government and industry or mentoring practices within specific research fields or scientific organizations.

5) **Expert Engagement** – This engagement involves science discipline authorities or research leaders acknowledged by their peers as experts and visionaries, e.g. Nobel Laureates, industry science prize winners, Australian Eureka Prize and Institute of Physics awards, and Australian Academy of Science award winners. This could include expert analysis or commentaries on new technology or recent scientific research discoveries and their likely societal or cross-discipline impact. Experts regularly provide key note addresses at conferences and their insightful presentations and critical analysis is regularly sought by industry, field specialists and the general media.

In addition to utilizing this organizational schema, PSTs are also challenged to communicate their understandings of science using creative multimedia artifacts. The rationale for this is to encourage the PSTs to develop and practice skills in creating and critiquing visual images or multimedia which has now arguably become very much mainstream in contemporary educational communication. Multimedia channels such as, YouTube.com, Vimeo.com and Vevo.com already provide access to a multitude of video resources from which educators can source and share useful multimedia artifacts. It is considered essential that PSTs are skilled to select discerningly from these rapidly growing collections with such diverse quality.

Another innovative approach used in the unit encourages PSTs to review, articulate and defend their personal view of the Nature of Science (NoS). This approach was initially adopted to encourage PSTs to develop and refine their views of NoS and to assist them to form a more coherent view that they felt more confident to share and discuss. Although there has been considerable research into the views of NoS held by a wide cross-section of the community, from the general public to students, scientists and science educators, there appears to be far less research literature which reports on ways of developing activities by which PSTs can effectively construct and articulate a coherent personal view of NoS. In initial workshops the PSTs are introduced to a number of provocative statements about NoS in a collaborative activity outlined by Cobern & Loving (1998). In line with the approach advocated in Cobern and Loving's paper the PSTs are encouraged to work initially as individuals and then form larger and larger groups to select or reject (by consensus) deliberately provocative statements about science designed to align with one of six broadly identified views of NoS. Through peer discussion and debate, PSTs are encouraged to construct and revise their view of NoS and to acknowledge changes in their positional understanding.

This activity has been adopted because it does not privilege one view of NoS over another or encourage all PSTs to adopt one "currently acceptable" view, but reveals how contemporary understandings of NoS change and will continue to change over time. The NoS theme is periodically re-examined at key points throughout the unit and is seen as a mechanism for identifying and tracking changes in individual thinking about attitudes and values of science.

Methodology

This unit was successfully delivered in the second semester of the first year of the project and at the time of writing, is presently being offered for a second time in the project's final year. The unit was offered to practicing teachers and PSTs in mixed study mode, consisting of four face-to-face workshops each of three hours duration, alternating with five online study sessions providing a mix of research readings, media resources, collaborative activities, and peer discussion forums for completion. Although the initial unit cohort was small (n = 16) the findings indicate that greater research and analysis is warranted in the next iteration of the unit to enable a more effective evaluation of its impact on PSTs attitudes and practices. At the commencement of the unit all PSTs were invited to participate in the unit research and completed an initial online survey aimed at gathering data on their course pathways and areas of teaching specialization. The survey also asked teachers and PSTs to identify how confident and prepared they felt to successfully undertake the teaching of contemporary science.

At the completion of the unit all PSTs were invited to undertake a 30 minute individual face-to-face interview with an independent researcher. Only two (n = 2) PSTs agreed to be interviewed due to course workload demands and survey timing. Using a number of set questions, the interviewer sought to investigate the PSTs' understandings of the course intentions and to seek feedback from the PSTs on how successfully they thought the unit objectives were achieved. The scientists employed at the research facilities visited by the PSTs were also approached by the independent interviewer, however only two (n = 2) agreed to meet briefly providing only very limited feedback on their experience with the PSTs and their interviews. The impact of PSTs visiting research facilities and interviewing practicing scientists was explored during several workshops and although PSTs generally reported finding the experience to be positive and informative, the lack of feedback determined that this aspect warrants greater research in future programs.

Findings

The data collected from the initial online survey (n = 3) provided only brief insights into PSTs' course backgrounds and employment intentions. Understandably the PSTs indicated that they were choosing to undertake the unit to gain insights into the contemporary practices of science and to develop additional skills and understandings which they thought would be helpful for their classroom professional practice in teaching science and/or mathematics. Not surprisingly their articulated intentions closely reflected those of the unit objectives. During a unit workshop at which the lecturers and independent interviewer were present, the PSTs (n = 14) provided verbal feedback on a number of aspects of the unit. The majority of the PSTs reported finding the first assessment task, "the creation of a multimedia representation which reflects their personal view of NoS" highly challenging. Many PSTs discussed how they did not feel confident or skilled in creating and critiquing visual representations compared with the more traditional argumentative essay assessment task. This lack of confidence was also reflected by the number of clarifying questions fielded by the unit lecturers regarding the implementation of this assessment task. This view was also reported by the two PSTs who agreed to be interviewed at the completion of the unit. They both reported feeling apprehensive and ill equipped to undertake what they saw as a highly creative task. In conclusion, it was acknowledged that the PSTs in general reported a lack of confidence in addressing the task of designing and critiquing visual images or multimedia.

One of the more surprising findings was the impact acknowledged by the PSTs that the collaborative discussions about NoS (in workshops and online discussion forums) had on building their confidence and ability to communicate a coherent and more contemporary view of science. A majority of the PSTs spoke of how their thinking and view of science had changed during the unit from one in which they originally privileged understandings of science or mathematical content to one with a broader understanding of the processes by which science is undertaken. This acknowledged shift was evidenced again by several of the PSTs directly in their multimedia representations and in comments made in their second assessment task. However in this first unit completion there were no opportunities to investigate or witness the implications that this changed view may have on influencing or reshaping their classroom professional practice.

On reconceptualizing a personal view of NoS, the PSTs reported greater self-confidence in constructing and justifying a personal coherent view of NoS and an improved ability and confidence in discussing and communicating NoS understandings across a range of professional settings:

> *Student (2) – "You know you always start this going, oh [I] already know this, [but] ... really talking about it [NoS] and kind of expanding that understanding was really good. ... I came out [after the unit] with a fairly different kind of conception...than I started with of what science is and what's core to it."*
> *Student (1) – "Questioning and actually reflecting on ... what I think about science and what other people think about science and trying to figure out ... what you know, what a coherent view is because a lot of these things aren't ... necessarily explicitly looked at ..."*
> *Student (2) – "If I was doing an interview for a science position I think it gives me a better understanding to talk about science education in a way that I think would stand out to employers, compared to people who hadn't done this unit or something similar."*

Several of the PSTs also reported that since visiting a research facility and talking to "real" scientists they now felt that they had improved understandings of contemporary science practices and how science is undertaken by scientists. Many of the PSTs acknowledged that before their site visits they knew very little of how "big" science is undertaken in world leading centers of excellence and their views were limited to highly contextualized educational experiences in undergraduate labs or even earlier high school settings:

> *Student (1) – "Yeah that was really good. I enjoyed ... the interview part [of] the site placement and talking to a working scientist and finding out what they value ... the importance of creativity and collaboration and what they ... know."*
> *Student (2) – "There was a few things that ... I wouldn't have thought was important [before doing the unit] that when I got to do ... the interview [with the scientist] towards the end of the subject ... a lot of things came up that we'd talked about ... and it was ... confirmed ... by the working scientists."*
> *Student (1) – "For example in science education our experiments work ... [this] is not what it's like in actual science. You don't know the outcome of ... the actual experiment."*

Conclusion

The researchers openly acknowledge that the preliminary findings from the single unit offering are quite limited in scope. However, the general findings from the interviews, workshops, and assessment tasks suggest that many of the approaches and activities used throughout the unit were largely successful in achieving many of the intended unit outcomes. A surprising finding was that encouraging the PSTs to re-conceptualize their personal view of NoS proved much more powerful and engaging than originally anticipated. Participants were keen to revisit and challenge their ideas throughout the course and to actively explore and debate alternate views. The changing personal view of NoS also provided insights into how their understandings of contemporary sciences were changing over time. Some students were reportedly surprised at the impact that robust discussion and debate had on changing their long-held views.

Constructing a coherent contemporary view of NoS also appeared to provide participants with language and confidence to engage in professional discourse which challenged and further enriched their understandings of science. Several participants self-reported improved confidence and competence in their professional practice when exploring science with their students as a way of knowing and understanding the world.

The research center site visits and interviews with practicing scientists were also reported to be highly informative and although the conversations and experiences were diverse, the workshop discussions proved very rich in building contemporary views of science practices.

The initial findings raise many questions about the success and impact of this unit on shaping PSTs views of NoS and adopting teaching with a contemporary view of sciences and their authentic practices. Further research will be undertaken and reported when this unit is next delivered.

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