A teacher professional development model for teaching socioscientific issues

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This paper describes the development and implementation of a three-pillared model for teaching socioscientific issues: teacher professional development; curriculum resources; and classroom support. A professional development program and curriculum resource based on the socioscientific issue of climate change was trialled with 75 Western Australian secondary science teachers. Teachers responded positively to the workshops and curriculum resource and indicated a willingness to use some or all of the activities in their classes. Two of these teachers have subsequently trialled the curriculum resource. These classes have been observed and feedback provided. This support aims to develop and maintain teachers' confidence in teaching socioscientific issues such as climate change.

INTRODUCTION

In the contemporary world, citizens are being required to make evidence-based decisions using their scientific knowledge at an ever-increasing rate. Public discourse about controversial issues such as the environment and genetically modified food occurs daily and to take part in this conversation, global citizens, including school students, need to be scientifically literate. Scientific literacy, also known as 'citizenship science' (Kolstø, 2001) is involved in many decisions regarding personal, community and global issues and encompasses skills in evidence-based decision-making. One way to develop students' scientific literacy is through the study of socioscientific issues (Sadler, Chambers & Zeidler, 2004).

Socioscientific issues are topics with a scientific basis which are important to human society, such as climate change and vaccination. These controversial issues have a wide range of views in society and often involve multidisciplinary, contested science. Students need current scientific understanding as well as evidence-based decision-making skills to comprehend the public debate. Climate change, which is the focus of this paper, is a socioscientific issue. The importance of evidence-based decision-making has manifested its inclusion in two of the seven aims of the Australian Curriculum: Science and is recommended as content descriptions in Science as a Human Endeavour (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2015).

To develop students' evidence-based decision-making skills, argumentation strategies can be used in the science classroom. Argumentation is the process of formalising an argument and encourages students to consider evidence when presenting and defending decisions in a logical and persuasive manner. Science teachers feel they already include argumentation to some extent in their classroom (McDonald & Heck, 2012), however research indicates this is not the case (Driver, Newton & Osborne, 2000). One study showed that in 34 observed science classes there were only two cases of tasks involving group discussion. In these discussions, little guidance was offered by the teacher and some difficulty was observed by groups in dealing with the social dynamics of the discussion (Newton, Driver & Osborne, 1999). Classes of today may have more opportunity for group discussion, however recent research shows teachers lack knowledge of argumentation and associated pedagogical strategies (Sampson & Blanchard, 2012).

The benefits to students' conceptual understanding of learning argumentation are well documented. Dawson and Venville (2010) found that students' conceptual understanding could be improved by the inclusion of socioscientific issues and argumentation skills in a genetics topic.

They proposed that students were using their scientific knowledge and language in a novel way within their arguments, which reinforced conceptual understanding. Processes such as argumentation which focus on higher-order thinking can also be of benefit to lower ability students (Zohar & Dori, 2003). Teachers' beliefs, however, are the opposite, with many believing that lower ability students lack the capability to participate in argumentation (McDonald & Heck, 2012). Scaffolding questions to focus students' thinking would be beneficial for all students but especially useful for lower ability students in producing a quality argument.

With the inclusion of evidence-based decision-making in the Australian Curriculum (ACARA, 2015), and the proposed benefits of argumentation, it is important that teachers include teaching strategies addressing this process in their science classroom. Given teachers' lack of argumentation knowledge and pedagogical strategies, many would benefit from formal professional development in this area. This paper proposes a model for a teacher professional development program aimed at improving their use of augmentation in the classroom through the introduction of discussions on socioscientific issues. This model includes three pillars: professional development, curriculum resources, and classroom support (see Figure 1). The interaction and ultimate intersection of these three pillars, underpins the goal of sustained change in teacher practice and improved student learning. This paper will focus on the development and implementation of the two pillars of professional development and curriculum resources.

PROFESSIONAL DEVELOPMENT

An online survey of 1,027 maths and science teachers (Garet, Porter, Desimone, Birman & Yoon, 2001) revealed the areas in a professional development program which have significant positive effects on teachers' self-reported knowledge and skills. These included a focus on content knowledge and active learning opportunities. In an argumentation context Zohar (2007) suggests that any teacher professional development (PD)

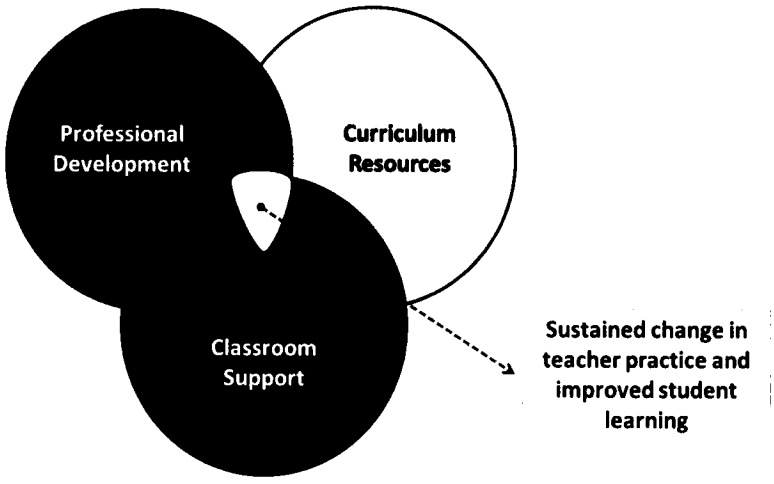

Figure 1: Proposed model for a teacher professional development program to improve students' scientific literacy.

program needs to consider knowledge of argumentation strategies as well as pedagogical content knowledge. Thus, a professional development workshop based on argumentation needs to include both content knowledge on socioscientific issues and argumentation and the modelling of teaching strategies consistent with argumentation.

To successfully implement argumentation into the science classroom, teachers need access to relevant resources and teaching activities. However, teachers may not have the time or inclination to design lessons that promote argumentation and have limited appropriate resources to assist them (Simon, Erduran & Osborne, 2006). The provision of curriculum resources which attend to the subject matter and include relevant teaching activities will facilitate the implementation of argumentation into the classroom, making teachers more likely to trial the strategy.

An example of a successful professional development program with supporting curriculum resources is PrimaryConnections (Australian Academy of Science, 2015). This primary science-based program links the teaching of science with literacy in primary school classrooms and provides a professional development program along with extensive curriculum resources that cover all conceptual areas of the Australian Curriculum: Science at all year levels from Kindergarten to Year 6. Recent published research on this program reported that teachers' confidence and enjoyment in teaching science was positively impacted by using PrimaryConnections (Skamp, 2012). The Ideas, Evidence and Argument in Science (IDEAS) project (Osborne, Erduran & Simon, 2004) is a UK-based professional development program based on

introducing argumentation and reasoning into science classrooms. This research-based program involves six half-day sessions accompanied by videos demonstrating exemplars of good practice, as well as curriculum resource materials. The program has been successfully used to develop teachers' argumentation knowledge and skills in several research studies (e.g., Simon & Johnson, 2008; McDonald & Heck, 2012).

Guskey (2002) proposed that any teacher professional development needs to focus first on changing teachers' classroom practices. He suggested that teachers needed to witness a positive change in student learning outcomes before their beliefs and attitudes would change. Given that teachers' beliefs and attitudes change *after* an improvement in student learning outcomes, it follows that in order to maintain teacher confidence and a change in practice, follow-up classroom support is also required. Thus, the professional development model of professional development workshop, curriculum resources and classroom support has been developed (see Figure 1).

CLIMATE CHANGE SCIENCE

Due to the global importance of climate change and the finding that many teachers would benefit from a professional development program focused on teaching socioscientific issues, it was decided to implement this model in the context of climate change. Climate change science is included in the Australian Curriculum area of earth and space sciences for Year 10 (ACARA, 2015). However, science teachers may lack the knowledge and strategies to teach the science of climate change (Wise, 2010). Some science teachers demonstrate knowledge gaps associated with climate change science, and can hold the same alternative conceptions as their students (Lombardi & Sinatra, 2013). Depending on their science background and teaching experience, science teachers may not have had any formal instruction in climate change science, or a limited exposure in pre-service teacher education. In one study, a focus group of secondary science teachers pointed out that although climate change was a controversial topic to teach, the topic did not did not fit easily into their normal teaching program due to its interdisciplinary nature (Gayford, 2002).

Common student alternative conceptions regarding the greenhouse effect, global warming and climate change are well documented (e.g., Lambert, Lindgren & Bleicher, 2012), as are strategies to support conceptual change in this area (e.g., Lombardi & Sinatra, 2012). When this study commenced, many curriculum resources were available both online and in science textbooks which addressed reducing the impact of climate change by decreasing fossil fuel consumption. However, there were few resources available which addressed the science of the greenhouse effect and climate change. Even fewer resources could be found which directly addressed common alternative conceptions related to the greenhouse effect and climate change (Choi, Niyogi, Shepardson & Charusombat, 2010). Our solution was to develop a selection of teaching activities based on the scientific understanding of the greenhouse effect and climate change that also addressed common alternative conceptions held by students.

PROFESSIONAL DEVELOPMENT IMPLEMENTATION

Research literature on professional development and our previous research on teachers' (Dawson, 2012) and students' understanding of climate change (Dawson, 2015) informed the development of a professional development workshop which aimed to:

- Increase science teachers' content knowledge through expert instruction;
- Inform teachers of students' alternative conceptions;
- Introduce teachers to teaching strategies to model argumentation and;
- Familiarise teachers with the curriculum resource.

In 2014, a four-hour professional development day was conducted for Western Australian science teachers. A total of 15 people attended the day. In addition, two 60-minute workshops were attended by approximately 60 teachers at

two science teacher conferences. The four-hour session was designed as a workshop with active participation by the teachers encouraged at all times. During the introduction, all of the teachers indicated that climate change was already included in their teaching, however, they were looking for ways to improve their teaching strategies. Several were enticed to the workshop by the curriculum resource and indicated they had trouble finding suitable engaging activities for their students.

Expert instruction on climate change science was presented by a marine geoscientist academic who researches and teaches about climate change. He presented data supporting human-induced climate change and introduced teachers to suitable websites. The predictions of changes to the climate were also discussed using scientific data. Teachers found this talk especially useful as they voiced a lack of knowledge of reputable websites with useable scientific data. This part of the workshop was viewed by teachers as a valuable opportunity to meet with a climate change expert and ask questions about the science areas they did not fully understand. Several teachers commented they now felt better prepared for student questions about human-induced climate change science.

Teachers were also introduced to common alternative conceptions held by students about areas such as the greenhouse effect, greenhouse gases, electromagnetic radiation, the ozone layer, and climate and weather (Dawson, 2015). Teachers were aware of some of these alternative conceptions. Some were novel to teachers, such as greenhouse gases are trapped by the atmosphere (instead of held there by gravity). A group discussion followed where teachers shared strategies to avoid or overcome some of these alternative conceptions.

Most teachers were familiar with the notion of socioscientific issues, although not necessarily the term itself, and all included them in some form in their teaching. Different strategies were discussed on how best to introduce them into the classroom, as one teacher indicated that classroom discussions on these issues can become volatile. Teachers agreed that either a controlled debate or group work using an envoy system or similar were the best ways to manage the discussion. It was interesting to note that most teachers included some form of research project within their climate change topic.

Teachers were introduced to Toulmin's (1958) model of argumentation and the different features of an argument: claim, data, backing, qualifier and rebuttal. Some were already familiar with this model, having used it in their classroom when teaching other socioscientific issues such as those in genetics and deemed it a useful structure for formalising students' arguments. Teachers who were not familiar indicated a willingness to include this model in their teaching by using the scenarios presented in the curriculum resource. They participated in one of the scenarios from the booklet, *Burning rubbish for electricity: Waste-to-energy plants* (Dawson & Carson, 2014). Following completion of the scaffolded questions, teachers engaged in a debate about the scenario as not all had come to the same decision. Anecdotal evidence indicated that this was insightful for the teachers as they experienced the type of discussion which could occur in their own classroom.

CURRICULUM RESOURCE DEVELOPMENT

To support the professional development program, a curriculum resource of teaching activities was developed based on the scientific understanding of the greenhouse effect and climate change. Anecdotally, teachers who did teach climate change were teaching this topic to Year 10 students. Thus the resources were aimed at Year 10 students but could be adapted for younger students.

A decision needed to be made early on in the resource development about the scientific terminology and whether 'global warming' or 'climate change' would be used. Within popular media, the terms are often used interchangeably. However, from a scientific point of view they are different in definition. Global warming is an average increase in the temperature of the Earth's surface or lower atmosphere. Climate change is a long-term change (usually measured over decades or more) in the quantifiable features of climate, such as precipitation, temperature and wind

speed. Both are almost certainly caused by the enhanced greenhouse effect. Climate change encompasses more atmospheric changes than just the temperature, including alterations in precipitation patterns and sea level (International Panel on Climate Change [IPCC], 2014). Thus, the all-encompassing term 'climate change' was used throughout.

To improve conceptual understanding, it is suggested that teachers need to be aware of students' possible conceptual frameworks and use cognitive conflict, analogies, and focus on modelling explanations (Treagust & Duit, 2012). These recommendations were considered when constructing the worksheets and activities used in the booklet. For example, in the 'What is the greenhouse effect?' activity the process of the greenhouse effect is compared to a car left in the sun with all the windows closed, which is an analogy more familiar to Australian students than that of a greenhouse.

An initial draft of the teaching activities was distributed to a Head of Science who was also a curriculum writer for chemistry, a biology Head of Science, an experienced physics teacher and an early career science teacher. Feedback proved helpful with suggestions about scientific wording and usage, appropriateness for year groups and formatting to improve ease of use. For example, when introducing carbon dioxide equivalents, the symbol 'CO_2e' was used, however it was highlighted that 'CO_2eq' is an easier symbol for students to understand.

Following revision of the booklet based on this feedback, it was developed into the following sections:

Introduction
What is the greenhouse effect?
Demonstrating the greenhouse effect
Socioscientific issues and argumentation

Within each section there are links to the Australian Curriculum, teacher notes, student answers and a student-centred activity. The teacher notes include enough information about the topic and activity that a teacher with limited climate change science knowledge would be able to teach that topic. The final resource is not intended to be a complete set of resources. It has been designed to supplement teaching of climate change science and to be effective when used in a limited amount of time. The resources can be taught consecutively over eight one-hour lessons, or be used individually in conjunction with a larger unit developed by the teacher.

SOCIOSCIENTIFIC ISSUES AND INTRODUCING ARGUMENTATION

To give students the opportunity to practise Toulmin's method of argumentation (1958), three different scenarios were included. These scenarios are based on factual situations which have occurred in Western Australia, although they are generic enough to be used elsewhere. Students are presented with a scenario and asked to make a decision about that situation. Through scaffolded questions, they formulate an argument which supports their decision using scientific evidence or data. When developing these scenarios, it was difficult to source authentic news reports or stories which directly related to conceptual understanding of the scientific processes of climate change. Most related to stories where greenhouse gases were being reduced through a reduction in fuel or electricity usage, or were about environmental issues causing a decline in biodiversity. All of the scenarios used in the resource were trialled with Year 10 students and the responses analysed. If students responded with a range of decisions and arguments, the scenario was determined to be useable. The three scenarios are described below.

HYDROGEN-FUELLED BUSES

Between 2004 and 2007 Transperth, the public transport provider for Perth, took part in an international study to assess the viability of using hydrogen-fuelled buses. These buses used a hydrogen fuel cell, which produces only water and heat as waste products. At the end of the trial, the Western Australian government decided the cost of this technology was too high and decided not to continue further. Students are asked if they agree with the government's decision.

WIND FARMS

A co-operative in the local farming community of Kojonup, Western Australia, has approval to construct Western Australia's largest wind farm of 74 turbines on agricultural land. At the time there was strong local opposition to the wind farm. Students are asked: if they were a local wheat and sheep farmer, would they agree to have two wind turbines positioned on their property?

BURNING RUBBISH FOR ELECTRICITY—WASTE-TO-ENERGY PLANTS

Two Waste-to-Energy plants are planned for construction in Port Hedland and Kwinana in Western Australia. Critics warn toxic emissions from the burning can lead to health and environmental problems, however supporters advise the plants can provide electricity as well as reduce landfill. Students are asked: if they were mayor, would they allow a Waste-to-Energy plant to be built in their council area

DISCUSSION

Many science teachers are not comfortable teaching novel and controversial topics such as climate change because of a perceived lack of knowledge and/or teaching strategies. This is unfortunate given the relevancy of socioscientific issues to students' lives. Teachers are missing an opportunity to engage students in authentic science and to develop students' scientific literacy. To overcome teachers' reluctance and build the confidence to manage a socioscientific issue in the classroom, a professional development program was developed, modelled on the three pillars of: professional development, curriculum resources, and classroom support. This paper described the development and implementation of the first two pillars of professional development and curriculum resource, in the context of climate change. This topic was chosen due to its global importance and a desire to provide

teachers with teaching strategies to implement climate change education in their classroom.

During the professional development workshop, teachers were given expert instruction in the science of climate change and became familiar with the teaching activities in the curriculum resource. Teaching strategies focused on teaching argumentation were modelled as an approach to improve students' evidence-based decision-making skills. Interestingly, the teachers who participated in the workshop, already included climate change in their teaching program and were looking for strategies and/or resources to improve their teaching experience. Some of the teachers had previous experience in teaching argumentation skills and all teachers considered it a useful strategy to formalise student thinking and to aid management of a classroom discussion on a controversial topic.

The curriculum resource has a selection of activities directed at teaching students the key science concepts in a small amount of time and has been designed to allow integration into a larger unit on climate change, or to be used as individual teaching activities. The resource is now available

online at http://spice.wa.edu.au/climate-change-and-the-greenhouse-effect/. The teaching activities based on argumentation use a series of scaffolding questions for students to make a decision and formulate an argument to present and defend their decision. These activities are in the context of climate change, however, the same questions can be used in any socioscientific context.

Overall, teachers reacted positively to the workshop and indicated a willingness to use some or all of the resources in the booklet. In particular, they noted the presentation from the geoscientist as a valuable element to increase their content knowledge. Several teachers were eager to trial argumentation in their classes and currently the scenarios are being trialled in two schools. The classes have been observed and feedback provided which the teacher can incorporate into future lessons using argumentation. Future lessons with different classes will also be observed and the development of students' argumentation in both oral and written forms will be assessed. This support will assist teachers in developing confidence in using these strategies and act as an impetus to continue including socioscientific issues and argumentation in the classroom.

CONCLUSION

The ultimate aim of this program is to attract science teachers to professional development workshops about teaching controversial issues. It is precisely these socioscientific issues about which our future global citizens, our students, require the knowledge and skills to start making informed choices. As the world develops into an increasingly complex global community, these choices can make a difference, big or small. As science educators, we are privileged to be a small yet integral part of this community by helping future generations to understand and improve their environment and the world in which they live.

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