"How do we teach argumentation in the new Australian Curriculum?"

Secondary science teachers' experiences in an argumentation-based professional development program

By Christine V. McDonald and Deborah Heck

The implementation of the Australian Curriculum: Science across the compulsory years of schooling (F-10) in most Australian states this year, requires science teachers to address the teaching of scientific argumentation in their classrooms. To attend to this challenge, we conducted an argumentation professional development program with practicing secondary science teachers, who possessed a range of teaching experience. Examples of the pedagogical activities implemented in the program will be outlined in this paper, in addition to a discussion of five teachers' experiences of the program sourced from pre- and post-intervention interviews. Shifts in participants' views of argumentation, participants' perceived implementation of argumentation, and barriers to the successful implementation of argumentation will also be discussed.

Introduction

The inclusion of argumentation in the school science curriculum is an important component of contemporary science education in many developed countries. The ability to make informed decisions about both personal and global issues is considered a key element of scientific literacy, thus emphasising the importance of engaging learners in the practice of scientific argumentation (Tytler, 2007). The mandated implementation of the Australian Curriculum: Science (ACARA, 2012) across the compulsory years of schooling (F-10) in the majority of Australian states this year, presents considerable implications for science teachers. Notwithstanding the demands of delivering what many teachers consider to be a 'content-heavy' curriculum, teachers will also be required to address the teaching of scientific argumentation in their science classrooms. Although a variety of definitions exist in the research literature, a commonly utilised definition of argument is provided by Toulmin (1958) as 'an assertion and its accompanying justification.' The concept of scientific argumentation manifests itself in two of the seven central aims of the curriculum, which states that all science students will develop:

> *...an ability to communicate scientific understanding and findings to a range of audiences, to justify ideas on the basis of evidence, and to evaluate and debate scientific arguments and claims; and an ability to solve problems and make informed, evidence-based decisions about current and future applications of science while taking into account ethical and social implications of decisions.*
>
> (ACARA, 2012, p. 3).

This presents a significant challenge for Australian science teachers, as the majority of these teachers have received no formal training in the teaching of scientific argumentation, nor have they engaged in the practice of scientific argumentation themselves. As such, it is somewhat unrealistic to expect teachers to successfully incorporate the teaching of argumentation into their classrooms without opportunities to develop both a personal understanding of scientific argumentation, and a suite of pedagogical strategies, approaches and resources for teaching argumentation in their science classrooms. Importantly, international research indicates that scientific argumentation is rarely incorporated in science classrooms, and not surprisingly, students generally show poor argumentation skills (Driver, Newton & Osborne, 2000). Research also indicates that most science classrooms continue to be teacher dominated, with students given few opportunities to learn about, or engage in argumentation. Clearly, a shift towards a pedagogical approach more aligned with promoting student-oriented dialogue and argumentation, and the provision of adequate training and support to enable teachers to effectively implement argumentative instruction in their classrooms is needed. For most Australian teachers, opportunities to develop these understandings will only be available through engagement in professional development programs.

Few studies have examined the influence of professional development programs on practicing teachers' argumentation (for exaple, Avraamidou & Zembal-Saul, 2005; Martin & Hand, 2009; Simon, Erduran & Osborne, 2006), with only one study identified in the Australian context (Dawson & Venville, 2010). The results from this small body of research are encouraging, with the majority of studies reporting positive outcomes for teachers engaged in professional development interventions focused on argumentation. Dawson and Venville (2010) reported favourable outcomes in developing one teacher's argumentation skills after engaging him in a brief, ninety minute professional development session. Importantly, the teacher who participated in the intervention was considered to be an exemplary biology teacher with nineteen years experience, and considerable expertise in facilitating classroom discussions. Thus, although these findings are encouraging, more studies are needed to examine how science teachers with differing levels

of teaching experience, engage in argumentation professional development. Our study addresses this gap in the research by exploring the experiences of five secondary science teachers, at various stages in their teaching careers, as they participate in an argumentation professional development program.

Method

Setting and Participants

Our study was conducted with practicing secondary science teachers from a variety of state high schools in the Gold Coast region of Queensland, Australia. Nine teachers from six schools agreed to participate in the project. Of the nine initial teachers, five participated in all aspects of the research project, and we purposively selected these five teachers to be the focus participants in the study. Pseudonyms have been used for all participants within this paper.

Three of the participants were beginning teachers (age range 25-35 years, all females), one participant was in his fifth year of teaching (age range 25-35 years, male), and one participant was an experienced teacher (age range 50+ years, male). Kate, Lisa and Rebecca were beginning teachers in their second year of teaching. Kate and Lisa were both currently teaching Year 8 Science and Physical Education. Kate was also teaching Year 12 Maths, and Lisa was teaching Year 12 Biology and senior Physical Education. Rebecca was not currently teaching any Science, although had taught Year 9 Science in the previous year. None of the female participants had explored argumentation in the past. Brian was in his fifth year of teaching and was currently teaching Year 12 Biology and Chemistry, Year 8 Science and Year 8 Maths. Peter was in his 10th year of teaching and was currently teaching Year 8 and 9 Science, junior Maths and senior Biology (Year 11 and Year 12). Both Peter and Brian expressed that they had previously explored argumentation through the use of debates in the classroom.

Data Sources and Analysis

Interview transcripts were the main data source in this study. Participants took part in semi-structured individual interviews prior to, and after, participating in the professional development program. We sought information from the participants regarding their previous science education, previous exposure to argumentation instruction, their views of scientific argumentation, general demographical information, and perceptions of the professional development program. Participants' interview responses were fully transcribed at the conclusion of the study.

The Professional Development Program

We conducted the professional development program over three days. Days 1 and 2 were conducted one week apart, and Day 3 was held approximately ten weeks later (due to the timing of the six-week summer school holiday break). Argumentation instruction was explicitly implemented during the professional development program via the direct teaching of various aspects of argumentation including instruction pertaining to the various definitions, structure, function, and application of arguments, and the criteria used to assess the validity of arguments (McDonald, 2010). Examples of these aspects of argumentation

SESSION	SESSION TITLE	SUMMARY
		DAY 1
1	An argument lesson	Introduced participants to what an argumentation based lesson might look like. The snowman activity uses a concept cartoon to show possible theories and engage students in exploring which of the two snowmen will melt first.
2	Argument in science	Explored what the term argument might mean in science and how this is different to the use in everyday language.
3	Constructing arguments	Explored the construction of arguments including the use of data, claims and warrants.
4	A model for argument	Introduced Toulmin's model of argument based on claims, data, warrants, qualifiers, backings, rebuttal and counter-claims.
5	Introducing argument in the classroom	Identified different ways teachers have engaged students in working with argument in the science classroom.
		DAY 2
6	Starting and sustaining argument	Engaged participants with classifying euglena as a plant or animal cell on the basis of argumentation, as an example of beginning and maintaining science argument with students.
7	Rounding off argument and counter-arguing	Identified possible ways to round off the Snowman and euglena activities. Explored the use of counter-arguments, counter claims and rebuttals.
8	Ways of initiating argument	Introduced and discussed eight different tools that can be used to engage students in argument in the science classroom.
9	Written argument	Introduced and discussed a number of writing frames that can be used with students to support student writing of arguments in science classrooms.
		DAY 3
10	Evaluating argument	Developed criteria for evaluating argument based on student output from the euglena activity and the Snowman activity making use of Toulmin's argument pattern to identify different levels of argument.
11	Group planning session	Participants reflected on their engagement with argument in their own science classroom and shared examples of these experiences and future plans.
12	Individual planning session	Participants engaged in individual and small group discussions about their plans to use scientific argument in their science classrooms with each other and the academics involved.

Table 1: Professional Development Summary drawn from IDEAS (2004).

will be discussed below. We incorporated a set of argumentation teaching materials developed from the Ideas, Evidence and Argument in Science Project 'IDEAS' (Osborne, Erduran & Simon, 2004), which have recently been successfully utilised to teach argumentation during the professional development of teachers (for example, Dawson & Venville, 2010; Simon & Johnson, 2008). A summary of the structure of the program is provided in Table 1. Participants were provided with a large folder of resources at the commencement of the program which contained all of the teaching materials utilised during the professional development program, and a complete set of the IDEAS resources consisting of two workbooks, a DVD and a CD (these materials are available to order from http://www.kcl.ac.uk/sspp/departments/education/research/crestem/steg/recentproj/IDEASorderform.pdf)

Our focus for Day 1 of the program was to introduce the concept of scientific argumentation, provide examples of what argumentation might look like in the classroom, learn to construct simple scientific arguments, and use Toulmin's (1958) model for argumentation (see Figure 1) to provide a structure for participants' arguments. We were interested in whether the participants would be able to recall any specific aspects of argumentation introduced during the professional development program, such as data, warrants, rebuttals, etc. During the final interview, Kate was able to recall the Toulmin model, and the term 'rebuttal', but was not able to verbalise any other terms from the framework. Lisa cited 'proposing an alternative' as a feature of argumentation, and was able to recall the terms rebuttal, warrants, claims and qualifiers, but was not able to explain them. Rebecca recalled backings, claims, rebuttals and counterclaims and exhibited some understanding of these components. Peter cited warrants and rebuttals, but was not able to fully explain the terms, and Brian expressed that he was already using some of the argumentation terms, such as claims and evidence, with his students.

We commenced Day 2 of our program with a summary of the previous session, and also sought to uncover our participants' reflections on Day 1 of the program. Our

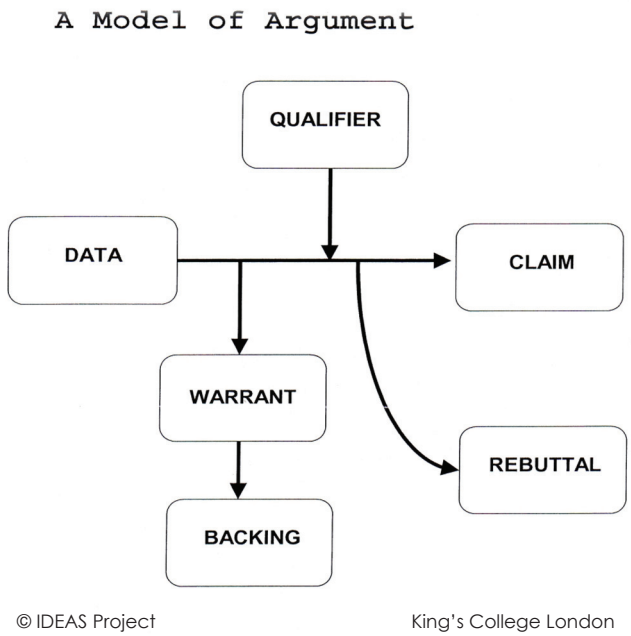

Figure 1: Toulmin's model of argumentation (from Osborne, Erduran & Simon, 2004).

focus for the second day was on initiating, sustaining and rounding off argumentation in the classroom, introducing the concept of counter-arguing, and developing written arguments. Participants took part in a variety of argumentation activities including an activity focused on the classification of Euglena (See Figure 2). We will discuss this activity in more detail, as all of the participants cited this activity as aiding their understanding of argumentation when prompted to recall specific argumentation activities during the final interview. In this activity, we provided participants with a set of evidence cards and asked them to work in small groups to construct an argument to support the classification of Euglena as either a plant or animal (or both, or neither). Participants were expected to base their decisions on the evidence provided, and construct arguments that contained data, warrants, backings, qualifiers and rebuttals. Lisa stated, *"...I thought that was really good and you could use that in a lot of ways just with general classification activities in biology"* (Lisa, Post-interview) showing an appreciation of being able to link the activity to her classroom instruction. Rebecca commented, *"Something that I liked was the euglena activity because that one made it really clear that things aren't always clear cut and that it's a matter of – in scenarios where there isn't a clear cut answer it's all the more important to state your backings and what have you to make your argument or to try to validate your argument."* (Rebecca, Post-interview).

***Euglena* - Plant or Animal**

Evidence that suggests *Euglena* is a plant	Evidence that suggests *Euglena* is an animal	Evidence that suggests *Euglena* is either a plant or animal	Evidence that suggests *Euglena* is neither a plant or animal

***Euglena* - Evidence Cards**

Euglena does not have a cell wall	*Euglena* contains chloroplasts
Euglena has a nucleus	*Euglena* is a single cell organism
Euglena can absorb food from its surroundings	*Euglena* confused early scientists
Euglena is normally green	The nucleus contains DNA and controls the cell activities
Chloroplasts enable a cell to photosynthesize	A vacuole controls the amount of liquid in a cell

Euglena swims through water	*Euglena* can make its own food
Euglena has a vacuole	*Euglena* is light sensitive
Euglena contains cytoplasm	*Euglena* can change its shape
Euglena lives in ponds and puddles	*Euglena* is temperature sensitive
Euglena can reproduce	There are more than two classification groups

Figure 2: Euglena classification activity (from Osborne, Erduran & Simon, 2004).

Another activity commonly cited as useful by the participants was the Snowman activity. In this activity, participants were provided with a scenario (see Figure 3) and had to develop an argument to support whether a snowman wearing a coat or a snowman without a coat would melt first. They were also provided with a page of evidence statements, and had to construct an argument to support their choice, and also rebut the argument that the alternative snowman would melt first.

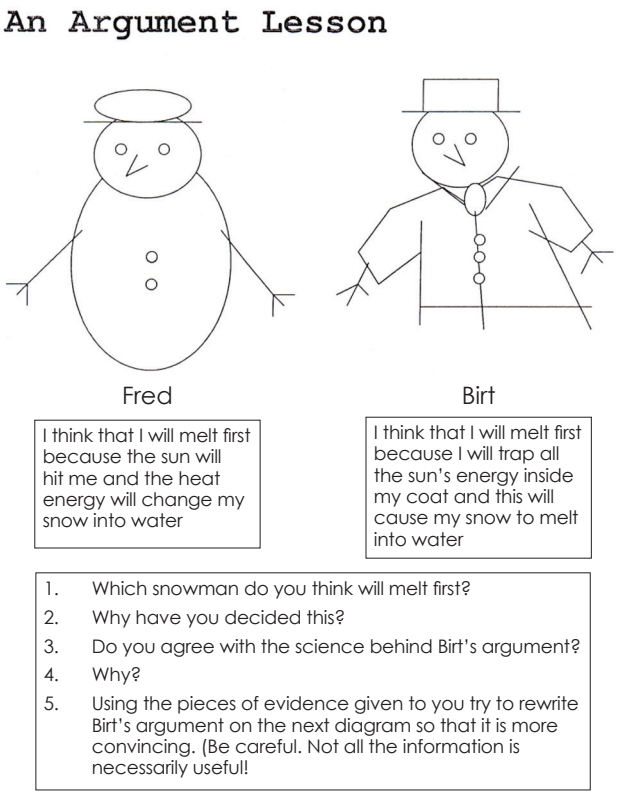

Figure 3: Snowman activity (from Osborne, Erduran & Simon, 2004).

We commenced Day 3 of the program with a review of concepts covered in the previous two sessions. This was particularly important as there was a ten week interval between the sessions due to the timing of the summer school holidays. The focus for Day 3 of the program was evaluating arguments, and planning for implementation of argumentation in the participants' own classrooms. Participants were provided with student argument samples and asked to evaluate the quality of the arguments presented. They were provided with evaluation prompts (see Figure 4), and were introduced to a five-level framework for evaluating arguments. We then worked with individual participants to ascertain their plans for introducing argumentation in their own classrooms. None of the participants had developed any lesson plans or activities focused on argumentation at this stage of the program. Thus, we sought to provide the participants with some guidance in planning for the implementation of argumentation into their own classrooms after the conclusion of the program.

Evaluating Argument

- Is there a claim? [Claim]
- Does the argument have data to support the claim? [Data]
- Does the argument link the data to the claim? [Warrant]
- Are there further justifications for why the data and claims are valid? [Backing]
- Is there any anticipation of the opposition and how these oppositions could be countered? [Rebuttal]

Figure 4: Evaluating argument activity (from Osborne, Erduran & Simon, 2004).

During the final interviews held in the fortnight after the conclusion of the program, participants were asked whether they had attempted to implement argumentation in their classrooms. Kate, Lisa and Rebecca stated they had not, but planned on doing so in the future. All three of these participants cited the professional development resources (folder of notes and DVD/CDs) as the source of their information to aid them in implementing argumentation. Peter stated that he planned on implementing argumentation in his classroom in the future, albeit in a limited fashion with his junior classes. When asked to explain the 'limited' implementation he stated, *"... I won't have a problem with fitting it in at the end of genetics when they've got all the information, and then getting them to do something small, an activity like that. So that won't be a problem."* (Peter, Post-interview). Brian was the only participant who had integrated many of the argumentation activities into his teaching, stating that he had instructed the students on the process of argumentation, and used a number of activities including the euglena activity, the snowman activity, the candle activity, and the pulse rate activity. He stated he was planning on integrating more of the activities in the future, including the pulse experiment and the water and steam scenario.

Results and Discussion

This study sought to explore practicing secondary science teachers' experiences in an argumentation professional development program. Some positive changes were evident in three of the five participants' views of scientific argumentation as a result of engaging in the program. No trends were identified in the data relating teachers' level of classroom teaching experience with more or less informed understandings of argumentation, although a trend that did emerge from the data analysis related to participants' perceived current implementation of argumentation in their classrooms. In addition, several barriers to the successful implementation were cited by the participants in the study. These findings will be discussed in more detail in the following sections.

Views of Scientific Argumentation

Participants expressed a variety of views of scientific argumentation prior to engaging in the professional development program. Three of the participants expressed limited views of argumentation, and two participants expressed more informed views. Kate expressed a limited understanding of scientific argumentation focused on imparting scientific knowledge in her response *"Trying to put across your point of view – not necessarily your point of view. The knowledge that you know about science to the kids in a way that they will understand and believe it as scientific knowledge as we know it, I suppose. Yes."* (Kate, Pre-interview). She held an everyday view of argumentation as 'fighting' expressing *"...I don't argue with the kids. They like to argue with me sometimes..."* (Kate, Pre-interview). Peter also expressed a limited view of scientific argumentation, which failed to recognise the importance of evidence to support a particular position, *"Basically trying to explain a point of view... Then you try and explain that to somebody else as best you can. Hopefully, they will be able to tell you that no, that's not correct or that's not their opinion for a particular reason..."* (Peter, Pre-interview). He also ascribed to the commonly held view of argument as 'fighting' stating, *"We would debate I suppose. It could be an argument*

with some of the kids because they're teenagers…" (Peter, Pre-interview). Brian also expressed a limited view of scientific argumentation which focused on putting forward ideas and arguing with the students, *"... I think also there's a case of, you know, creating or manifesting that sort of division in a classroom in saying, you know, you are the devil's advocate and you're, you know, the pro and, for, and against if you like. I want you to be the cynic. I want you to argue against me..."* (Brian, Pre-interview).

Although conveying uncertainty in her response, Lisa expressed a more informed view of scientific argumentation stating *"...I think the first thing that would come to mind would be being able to back up statements..."* (Lisa, Pre-interview). Rebecca was more confident in her response expressing an informed view, *"To me, the thing that immediately came to mind, was this idea of dissonance being argumentation obviously is putting forward different perspectives and trying to get people to talk about their different perspectives and provide justification for why that perspective is perhaps correct..."* (Rebecca, Pre-interview). These participants showed an appreciation of the importance of providing evidence to back up claims in their responses.

At the conclusion of the professional development program, participants were again asked to define scientific argumentation. Positive changes were evident in three of the five participants' responses. For example, Kate now expressed that scientific arguments require evidence and justification, and she no longer ascribed to the everyday view of argument as 'fighting.' This was evident as Kate indicated that students' need to, *"...have a decision about whether it's right or wrong, whatever it may be and they have to have evidence about the data and they have to be able to explain why... trying to justify their reason and their answers."* (Kate, Post-interview). Brian's response showed an appreciation of evidence in scientific argumentation, and the importance of argumentation in science education, *"...I think that it's a case of actually giving somebody the tools for which to express themselves in terms of, certainly for communication in science. You know, how do you reach conclusions and where's your evidence, and how's your evidence shaping up against something else and it's, so I see it as real, an essential element to science education."* (Brian, Post-interview). Rebecca defined scientific argumentation in a similar manner to her pre-interview response, although she did express an understanding of the structured nature of argumentation in her post-interview response, *"...To me, I know that it's very structured now, I've seen that, but if I was going to give you a broad statement as to what I think it is, I just think it's looking at all aspects of a topic and basically putting together a sound argument based on evidence that is in itself reliable and sound, verifiable. And then communicating that line of reasoning to explain a phenomenon of some sort."* (Rebecca, Post-interview).

Similarly to her pre-interview responses, Lisa expressed uncertainty when asked to define scientific argumentation, although again offered a generally more informed response, *"...scientific argumentation is basically having valid information to back up your statement ...it has to have knowledge behind it. It's not just being thrown out there to have an answer..."* (Lisa, Post-interview). Interestingly, Peter's view of scientific argumentation shifted from his pre-interview response, but not to an informed understanding of the concept. He viewed argumentation as providing students with knowledge and then posing a problem for them to solve, *".... So the whole point I got from it, is that you want to build their knowledge but you don't want to actually tell them, you want them to come up with as much as they can and basically come to the point, rightio, well we have a better understanding of what's going on now without having a definite answer to it..."* (Peter, Post-interview).

Participants' Perceived Implementation of Argumentation

An interesting theme emerging from the data analysis related to participants' perceived implementation of argumentation. All of the participants made unprompted references to the idea that they were already implementing argumentation in the classroom. For example, Lisa stated, *"...I found that with argumentation within your lessons I think we all do that to some extent already. The PD seemed to help sort of, I don't know, I think maybe put – allow you to put more emphasis on it. I think it really showed how important it actually is and you might use argumentation a little bit here and there but really you can use it at a much greater depth throughout all your classes..."* (Lisa, Post-interview). Similarly, Kate expressed that she already implemented argumentation, *"...to a certain degree"* in her classrooms, but added that the professional development program provided her with more in-depth knowledge about argumentation. Rebecca also expressed that she was already implementing argumentation, stating *"... I just couldn't help but feel the whole time when we were sitting there that a lot of what we talk about, I do... It's usually just on that more superficial level, to try to get them to consider why they've answered in such a way or to look at the validity of someone's comment... What I didn't find I was doing, something I haven't done a lot of, was actually structuring that scientific argument and bringing in that larger literacy component. So I think that's where this is going to be really good..."* (Rebecca, Post-interview). Peter also expressed that scientific argumentation is something that already goes on in classes, *"...but not formalised or anything like that"* (Peter, Post-interview), and Brian expressed that he joined the project because he sees a lot of what he does in the classroom in the project, and thus liked the idea of participating.

Barriers to Implementation

Several barriers to the successful implementation of argumentation emerged from a consideration of participants' interview transcripts. Importantly, the participants were not directly asked to cite possible barriers; these constraints were provided unprompted during the interview process. A summary of the cited barriers to implementation of argumentation is provided in Table 2.

All of the participants, except Lisa, expressed concerns for the successful implementation of argumentation in the classroom. Some participants cited a lack of student motivation as a possible constraining factor affecting the successful implementation of argumentation. For example, Rebecca stated that there has to be a certain level of intrinsic motivation within the students themselves to participate, *"...if you get a student who walks in and who isn't engaged from the start and they really couldn't care less about either theory, my concern is that if I'm going to send him off in a group where it's more autonomous then my concern is the level of engagement that kind of student would give."* (Rebecca, Post-interview). Brian expressed

CITED BARRIERS TO IMPLEMENTATION	INDICATIVE QUOTE
Student motivation	"They might talk about it for about two minutes or they might switch on when you come by, but I don't think they'll be actively, you know, getting into it initially. They need to see the benefit..."
Traditional teaching pedagogy 'spoon-feeding'	"But I think with a lot of kids that we get...they like the facts and things like that. They don't necessarily like to sit there and discuss."
Developmental readiness	"...you teach them something, they try and understand it and that's about as much as you get. They're not up to that stage where why are we doing this or where did you get that from..."
Interpersonal dynamics	"...it probably would work if one student wasn't there because that student's very boisterous and tends to make silly comments and things like that. So it would derail the whole process."
Time constraints	"But it's a vehicle that we've been encouraged to use but it doesn't fit all the time unfortunately"
Classroom management issues	"...I've got small classes, so it would work quite well with those kids".

Table 2: Cited barriers to implementation of argumentation.

a similar view stating that students, particularly junior students, don't naturally want to sit down and openly discuss issues. He suggested they would need to see the benefits of actively participating in these types of activities, and stated that he had tried implementing debates in the classroom with mixed results. One of the reasons he cited for this lack of success was students seeing it as too much work, or not appreciating the value of the activities. Another reason related to students wanting to be 'spoon fed' information. This trend was evident in other participants' responses, with many of the participants highlighting their students' pedagogical preference for a transmissive teaching style. For example, Peter expressed that many of his students don't like engaging in discussions, instead preferring him to provide them with scientific facts. Similarly, Kate noted that students generally do not question information given to them, and do not express a desire to think more broadly on a topic.

Closely related to the students' preferences for a transmissive pedagogical approach were some participants' reflected pedagogical approaches. For example, Peter stated that he was planning to implement argumentation with his junior classes in the future, but in a limited fashion, *"...I won't have a problem with fitting it in at the end of genetics when they've got all the information, and then getting them to do something small, an activity like that. So that won't be a problem."* (Peter, Post-interview). This response indicates his preference for a transmissive pedagogical approach consisting of giving the students information first, and then engaging them in argumentation as an 'add-on' to the lesson. A similar view was explicated by Kate who stated that good science teachers require knowledge and an ability to, *"...bring that knowledge over on to them (the students)"* (Kate, Post-interview). Recent research suggests that experienced teachers, in particular, may require an extended period of time to facilitate argumentation in the classroom, particularly if their preferred pedagogical orientation is a teacher-centred approach (Martin & Hand 2009).

Another constraint cited by many of the participants related to the developmental readiness of students. These concerns were particularly prevalent in the junior years of high school where many of the participants expressed a lack of confidence in their students' ability to cognitively deal with the process of argumentation. For example, when Kate was asked whether she saw a place for argumentation in the junior years she stated, *"...If you do it in a way that you want to get them thinking but there's some classes that are better than others obviously... They're up to you teach them something, they try and understand it and that's about as much as you get. They're not up to that stage where why are we doing this or where did you get that from..."* (Kate, Post-interview). Rebecca offered a similar response and noted that younger students may not be capable of engaging in argumentation due to a lack of higher order thinking skills, whereas older students have normally developed these skills. She suggested presenting argumentation in a more structured way to aid younger students' engagement in these types of activities. Peter also cited the importance of structuring argumentation activities for junior high school students to ensure they were able to engage in the activities effectively.

Some of the participants cited interpersonal dynamics as possible constraints to engagement in argumentation. Factors such as classroom dynamics, peer pressure and confidence were explicated by participants. Peter gave the following example of a dominant student as a case where argumentation would be difficult to implement, *"...He obviously watches a lot of science programs and reads some magazines and things like that. So he's quite clever, but to the point that he continually comes up with his opinion and it annoys the other students. So it doesn't stop him from saying it but it still annoys the other students to the point that they get a little bit sort of bored with the process..."* (Peter, Post-interview). Other examples cited included the presence of students who make inappropriate comments which disrupt the classroom climate. Similarly, some of the participants noted that peer pressure and a lack of confidence to offer opinions in front of the class were significant concerns in promoting engagement in argumentation. These concerns have been cited in previous studies (for example, McDonald, 2009). Other constraints cited by participants related to classroom management and time issues. Some of the participants commented that argumentation would be more effective with smaller classes, and would require sufficient classroom time to implement.

Recommendations and Future Directions

Teachers must not only develop their understanding and skills of argumentation, but also value the implementation of argumentation in the classroom (Sampson, 2009). This is particularly important for Australian science teachers as they attempt to implement this pedagogical approach as part of the new Australian curriculum. Although the participants in this study stated that argumentation was a useful pedagogical approach, they all expressed a belief that they were already implementing argumentation in their classrooms. This is a concerning finding, as teachers may not be as invested in learning about argumentation if they feel they are already

implementing it, thus devaluing the importance of argumentation as a pedagogical approach. In addition, viewing argumentation as an 'add-on' to the lesson, indicates a limited view of argumentation as a novel teaching strategy to be used after the 'real work' is complete. Importantly, some of the constraints to the successful implementation of argumentation cited by the participants in this study present significant concerns for educators. Factors such as the developmental readiness of students, time constraints, motivational aspects, etc., present challenges for our science teachers as they prepare to teach argumentation in their science classrooms, thus further research is needed to examine how these barriers to implementation can be managed and minimised.

Encouragingly, all of the participants expressed they had enjoyed engaging in the professional development program. Positive aspects of the program cited by the participants, included the provision of teaching resources (the professional development folder and DVD/CDs), engagement in small group work, and providing structure and clarification of the concept of scientific argumentation. All of the participants also expressed an interest in working with the research team in the future. We are interested in increasing the duration of the professional development program for future offerings as we recognise that short-term programs generally meet with limited success (Simon & Johnson, 2008). Consistent with previous research conducted over a short time period, large changes in participants' understandings of argumentation were not observed in this study, although some positive shifts were observed. Indeed, the IDEAS curriculum materials which underpinned the majority of the program were designed to be implemented over a longer time period, in addition to follow-up visits in teacher's classrooms. We aim to incorporate these recommendations in future programs, and are excited about the prospect of working with teachers in their own classrooms to facilitate the teaching of argumentation in science.

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References

(ACARA) Australian Curriculum, Assessment and Reporting Authority (2012). *The Australian Curriculum: Science (Version 3.0).* Commonwealth of Australia: Sydney, NSW.

Avaamiodou, L., & Zembal-Saul, C. (2005). Giving priority to evidence in science teaching: A first-year elementary teacher's specialised practices and knowledge. *Journal of Research in Science Teaching, 42,* 965-968.

Dawson, V. M., & Venville, G. (2010). Teaching strategies for developing students' argumentation skills about socioscientific issues in high school genetics. *Research in Science Education, 40*(2), 133-148.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84,* 287-312.

Martin, A. M., & Hand, B. (2009). Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study. *Research in Science Education, 39,* 17-38.

McDonald, C. V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching,* 47(9), 1137-1164.

Osborne, J., Erduran, S., & Simon, S. (2004). I*deas, Evidence and Argument in Science (IDEAS) Project.* London: University of London Press.

Sampson, V. (2009, April). *Science teachers and scientific argumentation: Trends in practice and beliefs.* Paper presented at the Annual International Conference of the National Association of Research in Science Teaching (NARST), Garden Grove, CA.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28,* 235-260.

Simon, S., & Johnson, S. (2008). Professional learning portfolios for argumentation in school science. *International Journal of Science Education, 30,* 669-688.

Toulmin, S. E. (1958). *The uses of argument.* Cambridge: Cambridge University Press.

Tytler, R. (2007). *Re-imagining science education: Engaging students in science for Australia's future.* Camberwell: Australian Council for Educational Research (ACER) Press. TS

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