Preservice Primary Teachers' Written Arguments in a Socioscientific Argumentation Task

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Abstract

This study assessed the quality of preservice primary teachers' written arguments in a socioscientific argumentation task. Five Australian preservice primary teachers took part in a science content course incorporating explicit argumentation instruction, and numerous opportunities to engage in argumentation. The quality of their written arguments were analysed using a framework adapted from Zohar and Nemet (2002). Results indicated that all five participants engaged in quality argumentation in the socioscientific task, with the majority of participants producing high quality arguments. Other findings indicated that participants' prior experiences may influence the content knowledge they draw upon to support their arguments.

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KEYWORDS: argumentation, socioscientific, pre-service

Introduction

Student disengagement with school science throughout the developed world is a critical issue for science educators and policy-makers. In Australia, Tytler (2007) reports that school science has not kept abreast of important changes in today's society, lacks an appreciation of the nature of science, and fails to include contemporary science practices in school curriculum documentation. As such, students do not recognise the relevance of science to issues that are important to them, and are not able to contextually link concepts taught in school science to their everyday lives. Similar concerns were voiced by Driver, Newton and Osborne (2000) a decade ago, highlighting the role of the teacher as an authority figure transmitting information in an uncontested fashion. Since this time, there has been an increased interest in argumentation in science education research. Lee, Wu, and Tsai (2009) conducted a content analysis of papers published between 2003-2007 in the three prominent internationally recognised science education journals (International Journal of Science Education, Journal of Research in Science Teaching, and Science Education), and found the majority of the top 10 highly-cited papers were concerned with argumentation (including informal reasoning), or scientific literacy.

Various rationales for the inclusion of argumentation in science education have been proposed by science educators. Advances in technological innovations and increasing globalisation require students of the 21st century to handle vast, and often complex, sets of information from a variety of different sources. Students are expected to be able to evaluate this information, and Jimenez-Alexiandre and Erduran (2007) stated "a significant aspect of such skills is the ability to argue with evidence" (p. 16). So, how does one define argumentation? In its most fundamental form, an argument is an assertion where the premises are stated as a means of justifying a conclusion (Govier, 2010). Osborne and Patterson (2011) stated that arguments attempt to justify uncertain conclusions with claims that are supported by data and warrants. They state the goal of argumentation "... is an attempt to persuade the listener of the validity of the conclusions. Engaging in argumentation is what fosters the critical disposition that is the hallmark of the practicing scientist..." (p. 636). Many scholars draw a distinction between the *process* or *activity* of argumentation, in which individuals engage in a critical dialogue in an attempt to justify a claim, or resolve a difference of opinion; and the *products* of argumentation which emerge, or may be distilled, from this process (Nielsen, 2013; Nussbaum, Sinatra, & Poliquin, 2008; van Eemeren & Grootendorst, 2004). The term *argumentation* is typically utilised to describe individuals' or groups' engagement in the process or activity of argumentation, and the term *argument/s* used to describe the products of this process or activity (which may be represented in a variety of formats, e.g., oral, written or textual).

Despite the worldwide trend to incorporate the teaching of argumentation in science classrooms via recent reform recommendations and curriculum developments (Jimenez-Alexiandre & Erduran, 2007), and the findings emerging from recent research viewing argumentation as an important instructional strategy and educational goal for science education (Bricker & Bell, 2008); empirical research indicates argumentation is rarely effectively incorporated in science classrooms (e.g., Berland & Reiser, 2009; Driver et al., 2000; Simon, Erduran & Osborne, 2006). Previous studies indicated that most classrooms are teacher dominated (Crawford, 2005), with students given few opportunities to learn about, or engage in argumentation (Lemke, 1990), and teachers generally do not possess adequate skills to teach argumentation to their students (Newton, Driver & Osborne, 1999; Sampson & Blanchard, 2012). Attempts to remedy the dominance of teacher discourse in the classroom have occurred over the past 20 years (e.g., Ratcliffe, 1996, Solomon, 1992), with many researchers recommending a shift from teacher-centred to student-centred discourse (McNeill & Pimentel, 2010), to encourage more student-oriented dialogue and argumentation (Duschl, 2008; Simon et al., 2006). The provision of adequate training and support is required to enable teachers to develop both their conceptual knowledge and skills of argumentation, and pedagogical strategies to effectively engage students in argumentation in a student-centred classroom environment (Sampson & Blanchard, 2012).

Socioscientific issues

The inclusion of argumentation in the curricula is an important component of contemporary science education in many countries (e.g., AAAS 1993; Australian Curriculum, Assessment and Reporting Authority [ACARA], 2012; NRC 1996). Recent curriculum developments in Australia place an explicit emphasis on the importance of argumentation in science, with an expectation that all science students will be able to "...communicate scientific understandings and findings to a range of audiences, to justify ideas on the basis of evidence, and to evaluate and debate scientific arguments and claims" (ACARA 2012, p. 3). Many researchers (e.g., Driver et al., 2000; Duschl & Osborne, 2002;

Erduran, Simon & Osborne, 2004; Kuhn, 1993; Sampson & Clark, 2008) have proposed that participating in argumentation promotes the development of scientific literacy. The achievement of scientific literacy is evidenced in reform documents internationally (e.g., ACARA, 2012; NRC 1996), and a key requirement for the achievement of scientific literacy is "... to develop 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). The types of issues students typically engage with to develop these attributes are referred to as *socioscientific issues* (SSIs) in the science education literature.

Engagement in SSIs requires students to apply scientific concepts, principles and practices to issues which are also influenced by societal, political, ethical, and/or economic considerations (Kolstø, 2001, Sadler, 2009). SSIs involve ill-structured problems with uncertain solutions, and are often complex (Sadler & Fowler, 2006) and controversial (Sadler, 2009), in nature. As students can take a variety of perspectives or positions on these issues, SSIs entice students to engage in argumentation, in an attempt to resolve differences of opinion (Walker & Zeidler, 2007). Importantly, although informed argumentation on an SSI requires the application of scientific conceptual knowledge, Nielsen (2012a) posited "...though science is needed, it could never be the final arbiter in a socioscientific context" (p. 277). He stated that a consideration of the values a student brings to an SSI is crucial, as the decisions students make during their engagement in SSIs are influenced by the roles played by both scientific evidence and human values.

Sadler (2009) provides a comprehensive review of argumentation studies conducted within the framework of SSIs. Findings from several of these studies reported improvements in students' argumentation during SSI interventions (e.g., Dori, Tal, & Tsaushu, 2003; Grace, 2009; Pedretti, 1999; Tal & Hochberg, 2003; Tal & Kedmi, 2006; Zohar & Nemet, 2002). Sadler concludes that SSI learning environments provide useful contexts for developing learners' argumentation, although the degree of success in particular interventions is dependent upon the supports provided to students during their engagement in the SSI. Supports such as teacher scaffolding, explicit argumentation instruction, and engagement in reflective practices were found to be beneficial in many of the cited studies (Sadler, 2009). Importantly, no studies were identified in the review which examined preservice teachers' argumentation during their engagement in SSIs.

Preservice and inservice teachers' argumentation

Few studies have focused on the assessment and/or development of preservice and inservice teachers' understanding of argumentation. These studies have mainly been conducted during teacher education courses (preservice teachers) or professional development programs (inservice teachers) (Zohar, 2008). A handful of studies have been conducted with preservice teachers (e.g., Osana & Seymour, 2004; Ozdem, Ertepinar, Cakiroglu, & Erduran, 2013; Zembal-Saul, 2004; Zembal-Saul, 2005, 2007; Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002). Zembal-Saul et al. (2002) investigated preservice secondary science teachers' argument construction in a technology-enhanced environment focused on natural selection. Results indicated that engaging in the technology-enhanced environment enabled participants to construct claims that were linked to evidence, although many participants' arguments lacked complexity and exhibited limitations regarding the nature and use of evidence. In a recent study, Ozdem et al. (2013) examined 35 preservice elementary teachers' argumentation during their engagement in

inquiry-oriented laboratory tasks and critical discussions. Results indicated that preservice teachers constructed a number of different kinds of arguments, and that engaging in the inquiry-oriented laboratory environment and participating in critical discussions, provided discourse opportunities to support argumentation.

The most significant contribution to this small literature base stems from Zembal-Saul's work with preservice elementary teachers. In a recent publication (Zembal-Saul, 2009) she synthesised the results of three empirical studies (Zembal-Saul, 2004, 2005, 2007), and presented a framework for teaching science as argument. The framework places explicit attention on using an argument structure to guide classroom discussions, publicly reasoning while coordinating claims with evidence, and authentically engaging with the language of science. Results from the three empirical studies utilising different iterations of the framework indicated that, in general terms, the framework assisted preservice teachers in focusing their attention on the construction of evidence-based explanations.

The influence of professional development programs on inservice teachers' argumentation has also been examined (e.g., Avraamidou & Zembal-Saul, 2005; Dawson & Venville, 2010; Martin & Hand, 2009; Sampson & Blanchard, 2012; Simon et al., 2006), with findings from the majority of studies in this area reporting positive outcomes for teachers engaged in argumentation professional development interventions. While these results are encouraging, findings from some studies suggest that more experienced teachers may require more time to facilitate argumentation in the classroom, particularly if their preferred pedagogical orientation is a teacher-centred approach (Martin & Hand, 2009).

Thus, previous research has shown that the development of teachers' understanding of argumentation is possible via teacher education and/or professional development programs, although further empirical studies are needed to inform future strategies and practices.

Summary and Aim of the Study

The previous review has highlighted teachers generally do not possess adequate skills to teach argumentation to their students, and they require adequate training and support to enable them to develop their conceptual knowledge and skills of argumentation. Few studies have focused on the assessment and/or development of preservice and inservice teachers' understanding of argumentation, and findings from the handful of studies conducted in this area indicate that the development of teachers' understanding of argumentation is possible via teacher education and/or professional development programs, although further research is needed to inform future strategies and practices. To the best of the author's knowledge, no studies have examined preservice teachers' argumentation during their engagement in socioscientific contexts, and no research has been conducted on Australian preservice teachers' argumentation.

This research is part of a larger study exploring preservice primary teachers' epistemological views and argumentation in scientific and socioscientific contexts (see McDonald, 2010). The larger study incorporated an open inquiry laboratory task designed to provide opportunities for participants to develop and apply their understandings of argumentation in a *scientific* context, and a global warming task designed to provide opportunities for participants to develop and apply their understandings of argumentation in a *socioscientific* context. An analysis of participants' written arguments in the open inquiry laboratory task indicated the majority of participants did not engage in argumentation in the

task (see McDonald, 2013). Factors such as a lack of background science conceptual knowledge, the non-provision of alternative data, a lack of argumentation scaffolds, and epistemological factors such as whether participants perceived a need to explain their data, were cited as possible constraints to engagement in quality argumentation in the task.

This paper focuses on the quality of participants' argumentation in the global warming task (referred to as the 'socioscientific argumentation task' in this paper). In this paper a high quality argument is characterised by the presence of arguments, counterarguments and rebuttals supported by multiple justifications and an extended argument structure; a consideration of accurate and specific scientific knowledge; and the coordination of claims with all available evidence. The quality of participants' written arguments produced from engagement in the socioscientific task were evaluated using a framework adapted from Zohar & Nemet (2002). The specific research question examined in this paper is, "What is the quality of preservice primary teachers' written arguments in a socioscientific argumentation task?"

Method

Validity and the Role of the Researcher

A constructivist perspective (Denzin & Lincoln, 2000) was chosen to guide this study which recognises that a researcher's beliefs and ideologies influence all aspects of the research process, from the design of the research questions, through to the interpretations that are drawn from the analysis of data. Constructivist researchers recognise that it is not possible to eliminate the influence of the researcher, and instead aim to understand and document this influence. It is particularly important to describe my role in the present study as I designed and implemented all major phases of the study, and was the course lecturer in the classroom intervention phase of the study. I also marked and graded participants' assessment items in the course. As these factors raise validity issues for the study, a set of trustworthiness criteria (Guba & Lincoln, 1989) were applied. Prolonged engagement was achieved by engaging in a substantial involvement in the setting in which the study was based, to ensure a sense of rapport and trust was established with participants. This involvement allowed me to gain a greater appreciation of the culture of the context, and minimised any possible distortion of information from the study's participants. Rapport was well established, as contact with both the context site and its participants, was frequent and substantial. Peer debriefing with two science educators was utilised to ensure that the results and analyses of the study were clarified and viewed through multiple perspectives. This process enabled any biases in the reporting of the study to be identified and re-evaluated. Thick description was also used in the reporting of the study to allow the reader to make their own transferability judgments about the study. A dependability audit was incorporated that allowed the implementation of the study to be tracked and evaluated by outside parties. Importantly, confirmability was established by ensuring that constructions emerging during the study were able to be traced back to their original sources.

Participants

Five preservice primary teachers (three female, two male) enrolled in a science content course conducted at a large urban university in Queensland, Australia were purposively selected for this study from a larger pool of 16 potential participants. The following criteria were utilised to select the five participants for this study: 1) completion of all data collection task requirements in the study, 2) regular class attendance, 3) freely availed themselves for interviews and informal discussions, and 4) fully participated in all

classroom activities. The remaining 11 preservice teachers in the course failed to complete one or more of the data collection tasks implemented in the study, and were therefore not selected as participants in the study. As such, the findings of this study are applicable to the five participants purposively selected for investigation, and should not be generalised to other populations.

Participants were of Caucasian descent and middle class socio-economic status, and were enrolled in their second or third year of a four-year Bachelor of Education undergraduate degree (focused on the education of 5-12 year old students). Rachel was a 19 year old female who had studied general science to year 12. She was observed as a quiet, hard working participant who actively participated in small group and whole class discussions. Rachel achieved a grade of 5 on a 7-point scale for the course. Monica was a 21 year old female who had studied biology and general science to year 12. She was observed as an outgoing participant who also actively participated in small group and whole class discussions. Monica achieved a grade of 5 on a 7-point scale for the course. Sarah was a 20 year old female who had studied physics and biology to year 12 and was currently undertaking the honours program. She was observed as a quiet, confident and hard working participant who tended to dominate small group discussions, and actively participated in whole class discussions**.** She possessed strong background science conceptual knowledge, and expressed that she had previously learnt about the science content covered in the present course. She achieved a grade of 6 on a 7-point scale for the course.

Tom was a 30 year old male who held an Engineering degree, and had studied physics, chemistry and biology to year 12. He was observed as a confident, outgoing participant who tended to dominate both small group discussions, and whole class discussions. His contributions during discussions often included elaborate scientific explanations of concepts. He possessed strong background science conceptual knowledge, and was frequently observed to refer to his extensive science background. Tom achieved a grade of 6 on a 7-point scale for the course. David was a 46 year old male who had returned to complete his secondary education (studying biology to year 12 level) after many years in the workforce. He expressed a lack of confidence in his background science conceptual knowledge, and often referred to himself as a 'slow learner.' He was observed as an outgoing participant making substantial contributions during both small group discussions, and whole class discussions. His contributions frequently included examples from his previous life experiences. David achieved a grade of 5 on a 7-point scale for the course.

Context

The science content course is one of a set of three science electives recommended for preservice primary teachers who wish to specialise in primary science teaching at the end of their degrees. Classes were held weekly in three-hour sessions, covering an 11-week teaching period. The course incorporated an inquiry-oriented learning environment where core chemistry concepts were taught through a variety of inquiry-based methods such as engaging in laboratory-based investigations, evaluating case studies, questioning and evaluating scientific claims, analysing primary data, and engaging in discussions of controversial issues (ACARA, 2012). As part of the larger study, a series of course components were specifically embedded within the inquiry-oriented learning environment to provide opportunities for developing and applying preservice teachers' epistemological views, developing their understandings of argumentation, and providing opportunities for preservice teachers to engage in argumentation. An overview of the specific focus and

details of each individual course component is provided in McDonald (2010). Importantly, it is recognised that it not possible to eliminate the influence of other course components on participants' overall experiences within a course. As such, although this paper is concerned with exploring participants' argumentation, and a consideration of argumentation-related course components will be provided, information regarding how individual aspects of the course were interpreted and synthesised by each participant is difficult to determine.

Argumentation instruction was explicitly implemented during weekly classroom teaching sessions by incorporating teaching materials developed from the Ideas, Evidence and Argument in Science Project (IDEAS) (Osborne, Erduran, & Simon, 2004b). The IDEAS materials have been successfully utilised to teach argumentation during the professional development of teachers in recent studies (e.g., Dawson & Venville, 2010; Simon & Johnson, 2008). These instructor-led sessions highlighted the importance of developing a student-centred classroom learning environment to facilitate engagement in argumentation, and enabled participants to develop both their conceptual understanding, and skills of argumentation. Through explicit instruction, I was able to scaffold participants' developing understandings of argumentation by engaging them in activities such as evaluating evidence sources, examining the quality of data/evidence, discussing differences between counterclaims and counter-arguments, and using writing frames to effectively structure arguments. Toulmin's (1958) model of argument was also explicitly addressed, and participants were introduced to a multi-level framework for evaluating the quality of arguments (Osborne et al., 2004a) and attempted to apply the framework to sample arguments.

Participants were provided with opportunities to engage in group argumentation to apply their evolving understandings of argumentation during these sessions, which were implemented in Weeks 2-8. Importantly, although Tom, David and Monica cited engaging in the oral argumentation scenarios as an enjoyable aspect of the course, Rachel and Sarah stated they had not enjoyed participating in the scenarios. They expressed a lack of confidence in their perceived scientific knowledge compared to the other participants, in addition to perceived insufficient skills of oral argumentation. Although Monica expressed that she enjoyed taking part in the scenarios, she pointed out that she disliked some of the other class members' personalities, and Tom expressed that he found it difficult to talk to some of the students with less developed scientific knowledge. As such, it is difficult to ascertain the quality of participants' developed arguments whilst engaging in these scenarios, due to the cited constraints.

After the conclusion of the explicit argumentation sessions, participants engaged in an open inquiry laboratory task towards the end of the course. This task provided opportunities for participants to develop and apply their understandings of argumentation in a scientific context (see McDonald, 2013 for more details). Concurrently, participants engaged in a global warming task which provided opportunities for participants to develop and apply their understandings of argumentation in a socioscientific context, via a written essay. Participants indicated that engaging in the written task was one of the most enjoyable aspects of the course, and in contrast to the oral argumentation scenarios, did not cite any factors which constrained their ability to engage in the task effectively. As such, the quality of participants' written arguments in the global warming task is the focus of the present paper, and will be referred to as the *socioscientific* task throughout the remainder of this paper.

Data sources

The following section will outline the details of the socioscientific argumentation task which provided the data for this paper. Data pertaining to participants' previous science education and experience, and general demographical information (e.g., age, socioeconomic background, gender, etc.) were sourced from transcripts of initial and final interviews from the larger study (McDonald, 2010).

The first component of the socioscientific task consisted of two science briefs developed by Sadler, Chambers and Zeidler (2004) on the issue of global warming, which had previously been used to investigate high school students' epistemological views in response to a socioscientific issue. The science briefs detail fictitious accounts based on the views of two groups of environmental scientists holding opposing views on the issue of global warming. One group presents an anthropogenic view stating that global warming is primarily caused by humans, and the other group presents a contradictory view stating that the current increases in global temperatures are a natural phenomenon. Participants were provided with copies of both briefs and discussed their views with the class. Engagement in this process provided opportunities for the participants to support their views with evidence, and construct arguments to support their positions. After discussing and critiquing the various positions put forward, participants were required to conduct background research about global warming, and align themselves with one of the two position statements. Participants were explicitly directed to consult a variety of literature sources to support their arguments, in addition to providing counterarguments to rebut the evidence on the opposing side. They were required to present their arguments in a written essay, and the written essays were analysed to evaluate the quality of their arguments in this study. The written essays were completed individually by the participants.

Data analysis

Data analysis was conducted after the conclusion of the study. I coded all of the participants' written arguments in their essays. To ensure that the results were consistent with the evidence gathered, an assessment of the reliability methods for coding the data was required. In order to achieve inter-rater reliability, a second science educator experienced in argumentation analysis independently coded all of the participants' written arguments, in addition to evaluating the features of the socioscientific argumentation task. Inter-rater agreement was reached in all cases through a process of initial coding, discussion, re-evaluation and resolution of discrepancies, and final consensus.

Participants' written arguments were analysed using a framework adapted from Zohar and Nemet (2002). This analysis enabled an evaluation of the quality of argumentation in the task to be ascertained. Various argumentation analysis frameworks have been developed to examine learners' argumentation in science education (e.g., Clark & Sampson, 2006; Kelly & Takao, 2002; Lawson, 2003; McNeill & Krajcik, 2007; Osborne et al., 2004a; Sandoval & Millwood, 2005; Zohar & Nemet, 2002). An excellent review of the mechanics of several widely utilised frameworks based on a consideration of the structure of argument, content of argument, and nature of justification, is provided in Sampson and Clark (2008). Importantly, the choice of argumentation analysis framework utilised in a research study must be guided by the purposes of the research in question. As such, existing frameworks may need to be modified to suit the specific contexts and requirements of individual studies (Kerlin,

McDonald, & Kelly, 2010). Zohar and Nemet define better quality arguments as those which consist of multiple justifications and conceptually accurate scientific information. Poor arguments are characterised by the presence of weak or irrelevant justifications, and claims which are not supported by any justification are not categorised as arguments. The terms data, warrants and backings are amalgamated under the single umbrella term of 'justifications.'

Following Zohar and Nemet (2002), an analysis of participants' ability to formulate arguments, alternative arguments, and rebuttals; and to justify them, was carried out in this study. Alternative arguments are classified as arguments that contradict one's original opinion, and rebuttals are arguments that refute the counterarguments. The criterion for argument formulation was whether the written responses included a conclusion with at least one relevant justification. Responses that included a conclusion with no justifications, or conclusions with pseudo-justifications, were not considered to be arguments. Justifications were scored according to their number and structure. The score range for the number of justifications was 0-2 (0=no justification, 1=one valid justification, 2= two or more valid justifications). The score range for argument structure also ranged between 0 and 2 (0=no valid justification, 1=a simple structure consisting of a conclusion supported by at least one reason, 2=a composite structure, in which the justification is supported in turn by another reason, usually explaining why the first reason should be accepted). Thus, a score between 0 and 4 is possible for each developed argument, counterargument or rebuttal (i.e., the sum of the number of justifications and argument structure scores). A total score ranging between 0 and 12 is possible for the argumentation task in this study as the task consisted of all three argumentation components (i.e., arguments, counter-arguments and rebuttals). Refer to Table 1 for exemplars of scoring arguments, counter-arguments and rebuttals for the task.

Another important aspect of Zohar and Nemet's framework is a consideration of whether learners' incorporate scientific conceptual knowledge into their arguments. They utilised four categories of analysis to determine the extent to which scientific knowledge is considered in developed arguments: (a) no scientific knowledge is considered, (b) incorrect scientific knowledge is considered, (c) non-specific scientific knowledge is considered, and (d) correct, specific scientific knowledge is considered. Higher quality arguments are characterised by the inclusion of correct, specific scientific knowledge. These criteria were also followed in this study. Refer to Table 2 for examples of scientific conceptual knowledge categories of analysis for the socioscientific task.

In addition to Zohar and Nemet's consideration of the quality of arguments, counterarguments, and rebuttals, and the incorporation of scientific knowledge, an additional criterion was utilised to assess the quality of participants' argumentation in this study. The consideration of alternative sources of evidence, and the subsequent coordination of claims with available evidence, is an important aspect of high quality argument formation not assessed using the framework developed by Zohar and Nemet. This criterion is significant as learners may develop arguments, counterarguments and rebuttals supported by justifications, and incorporate relevant scientific knowledge, but fail to consider other possible sources of evidence, or not utilise available evidence when developing their arguments. According to Zohar and Nemet's framework, these arguments would still be classified as high quality arguments. This limitation of the current framework was highlighted by Sampson and Clark who stated:

> ...student's may construct elaborate arguments consisting of several relevant justifications that include accurate scientific knowledge...but the claim might still involve inaccuracies if the student's did not coordinate the claim with all available evidence. This constraint is significant, especially because justifications for scientific claims are often based on interpretations of data gathered across multiple experiments. (Sampson & Clark, 2008, p. 457)

Table 1
Exemplars of scoring arguments, counterarguments and rebuttals in the socioscientific task (Adapted from Zohar & Nemet, 2002)

Examples of arguments, counterarguments and rebuttals	Justification (single or multiple)	Structure (simple or composite/extended)
Argument - The actions of humans has caused global warming	*Single* - There has been a relatively significant increase in global temperatures in the past 100 years	Simple
Counterargument - Global warming is a natural phenomenon	*Multiple* - The Earth is entering a period of warming as it leaves an interglacial period lasting 10000 years The differing levels of solar radiation produced by the Sun at different intervals are effecting how much warmth is absorbed at the Earth's surface	Extended
Argument - Burning fossils fuels is the primary cause of increasing carbon dioxide levels in the atmosphere causing global warming	*Single* - Prior to the industrial era, concentrations of carbon dioxide in the atmosphere were approximately 280 ppm. Recent readings estimate the concentration to now be in the range of 375ppm	Simple
Rebuttal – Other factors cause carbon dioxide to enter the atmosphere	*Multiple* – Recent natural processes such as increased volcanic eruptions allow carbon dioxide to enter the atmosphere A weakening of the Earth's carbon sinks as part of a climate change feedback mechanism indicates the forests, soils and plankton are releasing carbon, instead of storing it	Extended

Thus, three criteria were used in this study to determine the quality of participants' written argumentation: (1) the development of arguments, counterarguments and rebuttals supported by justification, (2) the incorporation of scientific knowledge, and (3) the coordination of claims with available evidence. A high quality argument is characterised by the presence of arguments, counterarguments and rebuttals supported by multiple

justifications and an extended argument structure; a consideration of accurate and specific scientific knowledge; and the coordination of claims with all available evidence. Importantly, a participant who fulfils criteria (1) and (2), but fails to consider possible sources of evidence, or does not coordinate their claim/s with available evidence is not deemed to be engaging in quality argumentation.

Table 2
Examples of categories of analysis of science conceptual knowledge in the socioscientific task (Adapted from Zohar & Nemet, 2002)

Consideration of science conceptual knowledge	Examples of arguments in the socioscientific task
No scientific knowledge is considered	Large corporations are causing global warming because all they care about is money
Incorrect scientific knowledge is considered	The hole in the ozone layer has contributed to global warming
Non-specific scientific knowledge is considered	The increase in global temperatures is due to the burning of fossil fuels
Correct, specific scientific knowledge is considered	Humans have contributed to an increase in greenhouse gases by burning fossil fuels which release an extra two billion tonnes of carbon into the atmosphere each year

Results and Discussion

Results indicated that engagement in quality argumentation was evident throughout all five participants' written essays. All of the participants provided arguments, counterarguments and rebuttals supported with multiple justifications and an extended argument structure; and coordinated their claims with available evidence. Four of the five participants also incorporated specific and accurate scientific knowledge into their developed arguments. Thus, these four participants' arguments were considered to be high quality arguments as they fulfilled all three criteria used in this study to assess the quality of argumentation. On the other hand, David did not incorporate accurate and specific scientific knowledge into his developed arguments, relying on non-specific references and personal opinion to support his claims. Thus, his arguments were considered to be of a lower quality than the other four participants' arguments in this study. Refer to Table 3 for an overview of the scoring of argument/counterargument/rebuttal development and justification; participants' consideration of scientific knowledge; and the coordination of claims with evidence, for the socioscientific task.

Rachel, Sarah, Tom and Monica all formulated arguments, counterarguments and rebuttals supported by multiple justifications, and an extended argument structure in their essays. They incorporated accurate and specific scientific knowledge in their arguments, and used this information to justify their claims. A comprehensive consideration of available evidence on both sides of the debate was evident, and they used this information to

coordinate their claims with evidence. Thus, the written arguments presented by all four of these participants fulfilled all three criteria of a high quality argument. The following excerpts provide typical examples of the quality arguments provided by the participants in their essays.

Table 3
Scoring of argument quality for the socioscientific task (Adapted from Zohar & Nemet, 2002)

Participant	Arguments		Counter-arguments		Rebuttals	
	J*/2	S#/2	J*/2	S#/2	J*/2	S#/2
Rachel	2	2	2	2	2	2
Sarah	2	2	2	2	2	2
Monica	2	2	2	2	2	2
David	2	2	2	2	2	2
Tom	2	2	2	2	2	2

Participant	Consideration of scientific knowledge				Coordination of claims	
	None	Incorrect	Non-specific	Correct, specific	Consideration of alternatives	Coordination of claims with evidence
Rachel				√	√	√
Sarah				√	√	√
Monica				√	√	√
David			√		√	√
Tom				√	√	√

Note: J* - Justifications S# - Structure

In the first example, Rachel provides an extended alternative argument supported by multiple justifications challenging the anthropogenic view of global warming:

> As has been stated above, the Earth's average surface temperature has increased over the past few decades by 0.5 ºC-0.8 ºC, however it is important to note the temperature fluctuations that occurred over many centuries prior to this recorded data (see Appendix 6). This information was gathered by analysing tree rings for growth patterns and testing the temperatures found in air pockets of ice cores (Mortlock, 1998). This data provides evidence for the theory that the global temperature increases cannot be blamed wholly on anthropogenic influences, as these changes have been occurring as part of the natural variations for thousands of years. More significantly this data shows (Appendix 6) that these fluctuations occur at particular intervals and that at this stage in history, an increase in temperatures is due to occur. The recording of solar activity in relation to northern hemisphere land temperatures (see Appendix 7) shows a relationship between the solar cycle and the increase and decrease in temperatures (Britt, 1998) (Rachel, Global warming essay, p. 6).

She then provides a rebuttal to challenge this evidence:

> However, this research is limited because of its restriction to the northern hemisphere and the lack of reliability of the data gathered prior to the use of satellites. Unfortunately to ensure this theory is accurate, data will need to be gathered from the completion of the current solar cycle, which will not end for another two years (Britt, 1998) ... (Rachel, Global warming essay, pp. 6-7).

In the next excerpt, Sarah provides an effective example of the incorporation of scientifically accurate scientific knowledge to support the argument that global warming is anthropogenic in nature:

> Wuebbles and Jain (2001) discuss an extensive amount of data and evidence related to climatic change and global warming that has been collected over the past century (p. 100). Some of the changes that they discuss include increasing snowfall in Antarctic regions, increasing global mean sea level (by 1.8+/-0.7mm/year), increasing and heavy precipitation, longer growing seasons in the northern hemisphere (by 12+/-4 days), decreasing extent of sea ice and snow cover in the northern hemisphere (10% from annual mean of 1972), and a general increase in surface air temperature of about 0.65°C (+/-0.15°C) (Wuebbles and Jain, 2001, p. 100) or 0.7°C (Kessel, 2000, p. 162). These findings all suggest that global warming is indeed occurring and analysis of these trends has led to predictions that further heating of the Earth could range from 1-3.5°C (Kessel, 1999, p. 157) or 1-5°C (Wuebbles and Jain, 2001, p. 99) over the next 100 years (Sarah, Global warming essay, p. 2).

She then provides a comprehensive rebuttal challenging the evidence provided by anthropogenic supporters:

> The reliability and validity of these measurements is, however, difficult to assess. Current measurements of temperature are said to be very precise, as they are taken using satellites and Earth-based stations around the world (Marshall Institute, 2000) but such measurements only exist for the last 20 years (Kessel, 2000, p. 162), and earlier measurements are less likely to be accurate. As climate is described as the average weather over a period of 30 years (Jansen, 1999, p. 11), analysis of trends in climatic change requires data from an extended period of time and using older data leads to questions regarding the accuracy of the instruments used to measure temperature, and the calculations applied to the data to devise the mean global temperatures or changes in measurements. Kite (2001) supports this point by arguing that often when graphs are shown to demonstrate the climatic changes over recent years, average temperatures from hundreds of sites are used which may give a misleading representation, depending on which sites are chosen (2001, p. 224). Kite even suggests the possibility that the temperature around urban areas is the only location where temperature is increasing, whereas rural areas are decreasing in temperature (p. 225) (Sarah, Global warming essay, pp. 2-3).

David also formulated arguments, counterarguments and rebuttals supported by multiple justifications, and an extended argument structure in his essay. He considered available evidence on both sides of the debate, and used this information to coordinate his claims with evidence. Although David provided an accurate overview of the scientific principles of global warming in the introductory section of his essay, little specific scientific knowledge was utilised to support his claims and justifications. For example, many of David's arguments were supported by non-specific references and drew heavily on personal opinions:

> It can therefore be seen that to convince a public that already has an opinion on global warming, scientific data alone may not be enough to convert the stalwarts or sway the 'fence sitters.' Further, scientific data, particularly if not presented appropriately, could convey a condescending tone to some lay people, raising their hackles, changing their point of view and causing them to side with a group that speaks at their level. Convincing people can be a subtle and fickle thing. Presenting facts may have little or no impact on some people but mention something that strikes a chord in their psyche and their opinion could be swayed or cemented forever. ...And it could be that the public are sick and tired of the whole affair and are subconsciously siding with the Industrialists based solely on the fact that their rebuttal is simple, understandable and more importantly, unobtrusive (David, Global warming essay, p. 6).

Thus, although David provided claims and supported them with justifications, he often added his own personal opinion to the arguments he created, and hypothesised about possible consequences:

> ...Despite the Industrialists argument being more convincing, they are possibly a little late (and possibly by choice) in using their own data to support their campaign. Also, despite having almost limitless funds at their disposal to carry out their own research, they still appear to be content with letting the Environmentalists find and present data so as they can 'shoot holes' in it. They quite possibly have the view that if they give the Environmentalists enough rope they will hang themselves... (David, Global warming essay, p. 7).

The lack of integration of specific scientific knowledge into many of David's arguments rendered them to be of a lower quality than those formulated by the other four participants, although it is important to note they were still considered quality arguments. Importantly, Nielsen (2012a) stated that scientific information is not the sole authority utilised when learners make decisions about socioscientific issues, highlighting the important role values play during socioscientific argumentation. He stated that socioscientific argumentation is *practical* argumentation, and decisions made while engaged in these scenarios are often about what to *do*, not simply what is *true* (Nielsen, 2012b). Thus, although David attempted to integrate scientific knowledge into his arguments, he appeared to use this knowledge selectively to advance his personal views about the issue. Similar findings have been reported by Nielsen (2012a) who found that upper secondary students used scientific knowledge to advance their positions on socioscientific issues, and to authorise certain aspects of the issues as being more important than others for making decisions.

In addition, recent research conducted by von Aufschnaiter, Erduran, Osborne and Simon (2008) found that junior high school students drew on their prior experiences and knowledge when engaging in argumentation, and that high quality arguments were primarily attained when students understood, and were familiar with, the content of the given task. Students in their study tended to refer to aspects of the task they were familiar with from other contexts such as their own life experience, mass media, and prior school science lessons. This proposition is also supported by the work of Patronis, Potari and Spiliotopoulou (1999) who postulated that personal relevance may have a significant effect on learners' abilities to construct informed arguments. As David possessed relatively more years of life experience than the other participants (in a non-science related industry), it is not surprising that he appeared to draw on this experience during his engagement in the task.

Similar to findings reported by von Aufschnaiter et al. (2008) and Patronis et al. (1999), his references to his own experiences appeared to facilitate his engagement in argumentation in the task, although in this study high quality arguments were not developed due to a lack of integration of specific scientific knowledge.

Conclusion and Recommendations

The ability to make informed decisions about both personal and global issues is a key component of scientific literacy explicated in reform documents worldwide, thus emphasising the importance of engaging learners in argumentative practices (Tytler, 2007). A critical prerequisite for the development of learners' understanding of argumentation is a classroom teacher with a well-developed understanding of argumentation, and a desire to implement this approach in the classroom. This study was designed with this premise in mind, and sought to develop preservice primary teachers' understandings of argumentation in a science content course incorporating an inquiry-oriented learning environment, explicit argumentation instruction, and numerous opportunities to engage in argumentation. Specifically, this study assessed the quality of the preservice primary teachers' written argumentation in a socioscientific argumentation task. Results indicated that all five participants engaged in quality argumentation in the socioscientific argumentation task, with the majority of these participants producing high quality arguments. Other findings indicated that participants' prior experiences may influence the content knowledge they draw upon to support their arguments. This study has made a unique contribution to the field in that it is the first empirical study identified in the literature that has assessed preservice teachers' argumentation during their engagement in a socioscientific context, and it is the first study conducted in the Australian context that has examined preservice teachers' argumentation. Future studies utilising larger samples are needed to ascertain if these findings are representative of other groups. In addition, further research is needed to assess the effectiveness of other types of science teacher education programs in preparing preservice teachers to teach argumentation to their students.

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