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A Case Study of Water Education in Australia

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Abstract

What does it mean to be scientifically literate in relation to water? Is this understanding the same for water literacy? And what implications do these two concepts have for water education in Australia? In addressing these questions, this paper provides a snapshot of the similar and competing educational ideologies that underpin the concepts of scientific literacy in relation to water, and water literacy. An investigation of the Australian Curriculum (Science), and a small case study of pre-service education students highlight the degree to which one concept is favored over the other. This bias ultimately raises questions for water education in Australia, as it is not about whether the ACS or [future] teachers should be addressing issues associated with water, but rather how and to what end goal. This necessitates exploring the partial and political nature of any approach to educating about water, and highlights that not all approaches are equally as politically neutral or challenging.

Keywords

Science Education, Australian Curriculum (Science), Scientific Literacy, Water Literacy

1. Introduction

Water is considered to be the "gold" of this millennium, and accordingly, the UN named 2013 as the International Year for Water Cooperation. As such, member states of the United Nations adopted the Millennium Development Goals (MDG) that included improving access to safe drinking water and water education (Meganck, 2010). Investment in water education, and improving water literacy is deemed to be essential if the MDG targets are to be met. With increased water targets being proposed, it is apparent that there will be a great shortage of water technicians, engineers, managers, scientists, and educators globally. Indeed Africa will need a 300% increase in this area to make the water sector sustainable, while Asian will need a 200% increase. More importantly however, there is the need to educate for a scientifically literate populace who understands not only the science behind water, but also the historical, social, economic and political aspects associated with water management, quality, and distributions. Citizens who have this broad base knowledge are key to addressing the wa-

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ter issues that we face now and in the future. To emphasize this need Meganck (2010) states:

> in short, we need to foment a "water consciousness" as profound as the development around the anti-littering or wearing a seat belt campaigns. Primary and secondary school curricula must begin to include both natural and social science aspects focused on water and its importance (p. 80).

Meganck's plea raises questions about what it may actually mean to be water literate. Is science knowledge of water enough? Or are other knowledge bases essential to achieve this status? With certain international and national expectations around what it means to be water literate, what is Australia's commitment towards generating water literacy? And more over, what aspects of water education are Australian teachers comfortable teaching?

This paper will explore the above questions in an attempt to map out the current state of formal water education in Australia.

2. What Does It Mean to Be Scientifically Literate?

Viewed as a universal need, scientific literacy is driven by a demand for a well-educated labor force and the desire for informed citizens who can evaluate the information, claims and actions of others, based on an understanding of the complexity of issues, rather than on prejudice and bias, and be able to act on this understanding.

Previously the term "scientific literacy" emphasized scientific concepts, ideas and processes (Eisenhart, Finkel, & Marion 1996). This included: where and how to use scientific terminology; an ability to pose and evaluate arguments based on scientific evidence and to apply appropriate conclusions; and to understand and develop abilities to engage ways of working scientifically.

Evolving still, scientific literacy progressed from a solely science focused term. Strong critiques generated from the field of education argued that conceptual knowledge and conventional scientific processes were foregrounded attributes at the expense of skills such as reasoning and communication (AAAS, 1993; Eisenhart, Finkel, & Marion, 1996). Apple (1999) and Hodson (1999) argued, if conceptual knowledge is key, then who decides what type of knowledge the general public should have in relation to the vast breath of scientific knowledge. Further, Lemke (1990) and Roth & Lee (2002) contended that being scientific literate needs to be situated within a collective experience, rather than being thought of as an individual attribute. Students who are simply "receptors" of science facts and are able to read, write and talk science are not necessarily scientific literate, for to be considered literate in science, they must also understand the fundamental conceptual, epistemic and social dimensions associated with the scientific community. They must appreciate the collective view of what it means to do science, of how to think, communicate and argue in the beliefs and language of science. Adding to this critique, others suggest scientific literacy should imply investigating more socially and environmentally responsible science (Reveles, Cordova, & Kelly, 2004). While Ayala (2004) advocated:

> Scientific literacy implies the ability to respond in a meaningful way to the technical issues that pervade our daily lives and the world of political action… Scientific literacy is also required for informed public involvement in the political and public life of a nation… a participatory democracy will not be consummated if the import of the technical premises of political decisions with great economic consequence, and which affect the present and future welfare of a nation, can be understood only by a small fraction of the population (p. 394).

As such, for students to be understood as being scientifically literate, they need to understand not just scientific concepts, skills and processes: they also need to understand the epistemology of science (what its goals are and how it operates), so they can appreciate both the positive and limitation of this scientific worldview. Further, students need to be able to place all this knowledge within a larger social and environmental frame. This form of scientific literacy encourages students to use their critical and creative capabilities to investigate prevailing social, economic, political, and cultural agendas and issues that reflect the complexity of the modern science and society. It is hoped by placing science within a wider frame, students will form a more holistic picture of issues and learn skills and strategies that will motivate attitude changes and most importantly, encourage them to engage in the democratic processes available to them.

3. Understanding What It Means to Be Water Literate

Ideas about being scientifically literate and being water literate show complex and multi-layered understandings.

To be considered scientific literate, a person needs a holistic and action based perspective as described above, but in relation to what the international community considers it means to be water literate, less focus is placed on this holistic and action standpoint.

Internationally, educational goals about water depend on demographics, technology, economics and political approaches, social and policy structures and infrastructures and implicit and explicit assumptions about prior understandings. Even though these goals will vary depending on regional cultural, social, political and economic factors, it seems a common goal is to improve the progression of water related information to the end-users in order to persuade them to behave in ways that are socially desirable (Braga Jr., 2013). But these desires vary as parts of Africa, the Middle East, North America and Australia use far more water than can be naturally replenished, so they focus on water conservation. Other parts of the globe focus on water management, planning and technical skills as more than a billion people lack access to safe drinking water, 2.5 million lack adequate sanitation and 35 million people die prematurely each year from water related diseases.

In Australian, the Federal Government relates water literacy with an improvement in the populist understandings of the properties of water; the biological, chemical and physical science concepts associated with water issues; and gathering statistics and facts to dispel misinformation associated with water science, management and use (Department of Sustainability, Environment, Water, Population and Communities, 2011). This reflects the focus of water literacy within science curricula in other "developed" countries as core science concepts associated with water are covered in an integrated way that highlights a crosscutting concept perspective. For example, students learn how the different natural cycles are deeply connected, such as how the transfer of energy becomes an integral part of the water cycle. Or, likewise, how the concept of matter as having sub-microscopic structure and motion can explain evaporation and condensation. Adding to these core conceptual components, different countries suggest integrating varying degrees of understanding ecological, social, and economic systems into this frame, along with a deeper understanding of the natural and build environment, and finally, sustainability and civic responsibility.

NGOs also add their perspective as to what water literacy should incorporate. The Alliance for Water Education links water literacy to students' understandings of the intersections between their own water usage, their everyday life and being able to have an educated discussion around controversial issues associated with water (AWE, n.d.). They maintain that being water literate means students can calculate their individual water footprint and understanding that all foods and products required water in their production process. Not only should people understand how much water they use, but they should also understand what it means to have healthy watersheds. Along side this, is the knowledge of how human and natural systems maintain those watersheds. The focus is therefore on individual and more localised understandings of water, its movement, and implications for making wise, sustainable choices for water conservation. Reflecting globally, they suggest students should understand energy-water connections; water, health and sanitation; competing demands of agriculture, industry, urban populations and wildlife; ownership of water; water scarcity and water conservation choices (AWE, n.d.).

It seems therefore, that there are two evolving understandings of what it means to be water literate. One interpretation aligns with the above understanding of what it means to be scientific literate as it encourages students to use their critical and creative capabilities to understand a deeper sociocultural and political agenda. This perspective also suggests an action component, so the outcome is not just knowledge or understanding about water, but incorporates the application of this knowledge into decision-making processes or action elements. In this instance, students explore scientific concepts and daily interactions with water, and issues associated with sustainability, and are also encouraged to investigate deeper social issues around water such as a community's economic, political and governmental plans (emergency or otherwise) for water. This perspective could be called being scientifically literate in relation to water. The other perspective, which could be called water literacy, focuses more on understanding science concepts and asking students to apply this knowledge to investigate their individual water footprint to encourage wise water usage. This perspective does not encourage a deeper, more complex understanding of cultural agendas, and the economic and political decisions made within societies that ultimately impact how water is negotiated and managed. In this paper, the economic and political nature of water refers to this deeper social reflection on decisions and management of water within a society.

4. The Australian Curriculum (Science) and Water Education

In Australia science education is now governed by a national curriculum. The Australian Curriculum (Science) (referred to as ACS) guides what content is to be taught at each year level from kindergarten (referred to as Foundation Year) to grade 12. It is compulsory for all Australian teachers to use this curriculum and for every graduating student to have successfully met the competency requirements for each subject they have undertaken (ACARA, 2010). As such, to appreciate what competencies Australian students must successfully gain in relation to understanding water, it is important to examine what the ACS mandates teachers' focus on.

Not only do Australian teachers and students have a mandatory focus on the specific science concepts set out in the ACS, but these concepts have also become the basis for science education courses at universities.

As the discipline of science is mandatory up to Year 10, this paper will focus on the ACS from the Foundation year, to Year 10. Fundamentally, the ACS has 3 interrelated strands that explore Science Understanding (science content), Science as a Human Endeavour (how science relates to technology, environment and society) and Science Inquiry Skills (ways of working and thinking in science). These strands challenge students to explore science, its concepts, and nature through inquiry-based processes. The goal is for students to develop a scientific view of the world (ACARA, 2010). The Science Understanding component is divided up into Biological sciences, Chemical sciences, Earth and Space sciences, and Physical sciences. There are 18 references in total relating to water within the Biological sciences, Chemical sciences, Earth and space sciences, and Physical sciences from the Foundation year to year 10. In analyzing the ACS for references associated with water, if the same discipline and year level makes multiple references to water, then these references are just recorded once. For example, if Year 1 Biological sciences suggested related water topics, then all topics would account for just one of the 18 references found in the analysis.

Six of the identified water references relate to Earth and space science. These include: seasonal changes and weather patterns (Foundation year); short and long term changes in weather (grade 2); water as a resource (Year 2); the transportation, management, daily use and conservation of water (Year 2); how water can change the Earth's surface over time (Year 4); droughts and floods (Year 6); the water cycle and changes of states, management and human impact (Year 7); and the causes and consequences of climate change and water (Year 10). Five of the 18 references relate to the Biological sciences. These include: understanding that water is a basic need for living things (Foundation year); structural features for obtaining water (plants) (Year 1); what happens when water requirements are not met (Year 1); adaptations of living things to survive (Year 5); how physical conditions affect survival (Year 6); how ecosystems change due to droughts and flooding (Year 9); and how multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment (Year 9). Interestingly, most of the above points are taught in grade 6 or less. Four of the 18 curriculum references relate to the Chemical sciences, topics include: how water changes when it is heated and cooled (Year 1 and Year 3); the properties and behaviours of solids, liquids and gases (Year 5); reversible and irreversible changes (Year 6); and the solubility of common materials in water (Year 6). Again, these topics occur in grade 6 or below. The last component within Science Understandings is the Physical sciences. There are 2 references to water in this section and they relate to how objects move through water (grade 2) and how water can be used to make electricity (grade 6).

Four mandatory requirements relate to the strand Science as a Human Endeavour and are found within Year 5 - 7. The topics for this strand include: considering how best to ensure plant growth and making decisions about growing particular plants and crops (grade 5); looking at sustainable power sources from water; investigating early detection and management of catastrophic natural events; exploring institutions and locations where contemporary Australian scientists conduct research on catastrophic natural events (grade 6); and considering issues relating to the use, management, and recycling of water within a community (grade 7).

The last strand Science Inquiry Skills, provides suggestions about how a concept could be taught, but not the what. The what is explored in the other 2 strands as described above. This third stand mandates an inquiry based approach, rather than a chalk and talk model. From this perspective, modelling thinking and acting like a scientist by testing predictions or hypotheses and drawing conclusions in response to a question or problem, underpin science education. These investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations (ACARA, 2010). These investigations stress the process of collection and analysis of data and evidence but do not make any specific reference to content, such as the concept of water.

It seems that the content side of water is taught mainly in the lower years of schooling and the environmental and social sides to water are explored later. This could be due to the spiral nature of the curriculum, where concepts are taught in general, big-picture pattern in the early years. These early ideas reflect concepts that students have seen or have some direct knowledge of, like weather patterns. These generalised concepts are then built upon by adding more specific and focused conceptual understandings, such as the water cycle. This specific knowledge reflects on and reinforces previous knowledge the students have gained in earlier years. In this way students can understand how the water cycle and weather patterns interrelate.

By embedding the Science as a Human Endeavour strand requirements alongside the Science Understandings strand requirements, students investigate science concepts together with the importance of water in their everyday lives. For example, the Year 2 curriculum seeks to capture interest by asking students to identify and describe the location of water in their personal environment (ACARA, 2010). In Year 7, the ACS seeks to address the science of the water cycle and asks students to explore how human management has impacted this cycle.

The presence of the above concepts in the National curriculum is a strong start to ensuring the inclusion of water education in Australia; however, within the classroom, the teacher is responsible for the students gaining proficiency in these curriculum standards. Aligning instructional programs with these standards is only one part of the pedagogic puzzle. To teach effectively and confidently, teachers need to be knowledgeable and able to express their ideas comfortably. This poses a few questions: to what degree are teachers water literate themselves? What concepts associated with water education do teachers' feel comfortable teaching? And what does this mean for water education in Australia? If water education is influenced, to some degree, by the knowledge base and abilities of teachers, then these questions are important to investigate if we are to understand more fully the complexity of teaching and learning about water.

To seek a deeper understanding of [future] teachers' comfort levels and capabilities in relation to water education, a small case study was conducted.

5. Method

To provide a glimpse into the comfort levels of [future] teachers in relation to teaching about water, a small case study was conducted in Semester one, 2011 at a large multi-campus university in Queensland, Australia.

This study used an interpretative mixed methods approach. Interpretative mixed methods aligns with this research as it aims to "understand how individuals make meaning of their social world" and "allows for multiple views of social reality" (Hess-Biber, 2010: p. 104). The focus of this methodology is not specifically that it employs both qualitative (textual data) and quantitative analysis, but rather the standpoint that social reality is created through the interactions of individuals with others and with the world around them. It seeks to contextualize people's experiences. To this end, this research employed a survey method with quantitative measurement questions to frame the representative sampling while also employing qualitative questions to gain deeper insights into the comfort levels of the participating pre-service teachers with teaching about water and related issues.

5.1. The Participants

The 32 participants were drawn from an undergraduate, pre-service teaching cohort in their third year of a Bachelor of Education (Primary). They were enrolled in their second, and last, science education course. The total number of students in the cohort that year was 79. This represents a response rate of 40.5 per cent. There were only 32 students who attended the last lecture and all choose to complete the anonymous survey. Whilst gender and age data was not collected it can be assumed that the majority of respondents were female given over 95 per cent of the cohort were females.

5.2. The Instrument

The participating students were asked to complete a survey consisting of 13 questions to self-report on their knowledge and comfort with teaching about water. The survey investigated 6 themes relating to the pre-service teachers comfort with teaching about water: science concepts; social, political and economic issues; sustainability and the natural environment; Indigenous ways of knowing; government and community connections; and lastly, planning and emergency preparedness. **Table 1** shows the individual measures for each theme, the number of items within the questionnaire, and the scales used for each.

Data analysis occurred through an iterative process. For the closed questions, a frequency distribution chart allowed for a structured analysis, and highlighted patterns and common themes. The data from each open-ended

Table 1. Constructs of pre-service students water literacy.

Construct	Measured as… (open/closed question)	Number of questions
Science concepts	Closed questions Open ended questions	1 2
Social, political and economic issues	Closed questions Open ended questions	3 1
Sustainability and the natural environment	Closed questions Open ended questions	2 1
Indigenous ways of knowing	Closed questions Open ended questions	1 1
Government and community connections	Closed questions Open ended questions	2 1
Planning and emergency preparedness	Closed questions Open ended questions	2 1

Note: One of the open questions asked what the teachers would like to learn more about to increase their comfort levels with teaching the above concepts—this question was included more than once in the above chart.

question was organized into a chart that allowed for an analysis of common themes and patterns, and from there, the frequency to which these themes were mentioned. Deviations to these patterns, interesting statements, and relationships between open-ended questions and the closed and scaled questions were explored. The results are communicated in relation to the above six themes.

5.3. Reliability and Validity

The process of developing the survey robustly explored and addressed issues of reliability and validity. To address validity, or the extent to which the survey measured what it was designed to measure, numerous steps were taken. Issues associated with content validity were addressed early in the development of the survey with insights emerging from field notes and informal semi-structured interviews with students around the teaching and learning of water and its related issues. Important issues also emerged from the literature review. The survey included all the identified issues and included multiple ways of measuring and recording students' opinion and experiences. Specific closed questions were asked, along with open-ended questions to formally encourage participants to report on issues they felt were important, and from their own point of view. Specific questions were adapted or were informed from measures found in related literature either in terms of the development of the measuring instrument or as a content source for a question. To address the reliability and face validity of the survey, in addition to the pilot work, colleagues and students (not enrolled in the target course) were asked for comments and suggestions. This encouraged the modification of questions so the participants could more easily understand them. The final survey was appropriate for the student body as it was of reasonable length, used familiar wording and was well presented. This face validity check also confirmed construct and content validity as feedback supported that the survey was reflective of the classifications and complexity of the six themes. Further, to facilitate reliable data, the survey was conducted during the semester period, so the respondents were still engaged with the teaching and learning of science education. An academic who was not teaching into that specific course gave instructions about how to complete the survey and its importance. Students were told that it was voluntary and anonymous.

6. Results

Of the 32 participants, 84% (n = 27) indicated they would feel comfortable teaching the scientific concepts associated with water education. This represented the highest response, indicating a strong comfort level with teaching this aspect of water education. Teaching the implications of water in relation to the natural environment was the next most indicated response with 69% (n = 22) of the participants indicating their comfort. Teaching about the social implications of water, and teaching about sustainability issues, both received 62% (n = 20). Next was the participants' comfort with teaching community issues at 56% (n = 18).

Comfort with teaching flood and/or drought emergency warning systems was indicated by 44% (n = 14) of the participants, and comfort with teaching about the economic implications of water was indicated by 41% (n = 13) of the participants. Teaching about flood and/or drought planning, political implication of water and government plan/uses received 34% (n = 11), 25% (n = 8) and 21.8% (n = 7) respectively.

The lowest scoring aspect, indicating the participants' lack of comfort with teaching this aspect of water education was Indigenous ways of knowing in relation to water. Only 9%, or 3 of the participating pre-service students indicated this.

7. Discussion

So what does this study highlight? The results of the small survey highlight that the majority of participants feel comfortable teaching science concepts associated with water, as well as aspects relating to the nature environment, sustainability and social and community issues. This supports the concept of water literacy as the focus is on understanding science concepts and asking students to investigate their water footprint. To be considered water literate, students and teachers need to understand the intersection between the science concepts that relate to water, their own daily water usage and be able to engage in educated discussions around controversial issues associated with water. This mirrors the ACS focus which aims to increase understandings of science concepts associated with water and to a lesser degree, increase an individual awareness and responsibility towards good personal management and conservation practices. It is assumed this new knowledge will guide practical judgments and promote changes in individual behaviour leading to the adoption of greater individual responsibility around water.

This study also highlights that pre-service teachers are not as comfortable teaching about the political and economic implications of water (how economic and political decisions are made within societies in relation to water, and their impact), emergency planning and warning systems, government plans and uses of water and Indigenous ways of knowing in relation to water: topics usually associated with being scientifically literate in relation to water. To be scientifically literate in relation to water, students need a broad cultural, socio-political and economic understand of water issues, along with a deep understanding of science and scientific knowledge to fully engage in vital community discussions and actions, and to incorporate water conservation practices within their daily lives, and the lives of their community. And so will their teachers. However, if the teachers are not comfortable with this knowledge base, and if it is not a focus of the ACS, then it is unlikely they will teach from this perspective.

In the ACS, skills associated with generating social change or actions are not promoted, as knowledge and individual action are the desired outcomes. This focus on individual use of water may help students see how water impacts their lives, but it may not help them connect to larger economic, social and political perspectives associated with water in their local, national and global communities. It is at this larger social level where debates about water will occur and vital decisions will be made. If the individual agenda is the main focus of what is taught about water, then what fails to be known is the prevailing invisible social, cultural, economic or political conditions that create and seek to maintain the political and economic status quo around controversial issues. To this end, what is left out of water education highlights that education can never be neutral as educational agendas seek to maintain and reproduce particular knowledge bases within safe and politically acceptable limits.

This raises questions about the underlying agenda for educating students about water. Science education itself is reflective of many underlying agendas, whether they are cultural assumptions about the role of education in society, philosophies about what effective or ineffective education looks like, or beliefs about student learning. Therefore, our understandings of science education are not neutral, but ones that favour unacknowledged cultural agendas. Examining these agendas can reveal how knowledge and knowledge generation processes are inseparable from ideologies, philosophies, history and social institutions. This highlights that teaching and learning science reflects different ideologies, and each ideology has political implications. In relation to water education: should we be educating for water literacy or for being scientifically literate in relation to water. Should we be aiming for a general, politically neutral understanding of social issues or a deeper, more thoughtful examination of issues that promotes social critique and [political] action in students? Should we, as science teachers, be offering the potential for understanding current political, economic, social, cultural and ecological ideas and values, and the skills to bring about change?

If both future teachers and the ACS support the concept of water literacy then this understanding becomes the benchmark for good teaching about water. It can also become the basis for "legitimately" disqualifying and marginalizing alternative concepts such as being scientifically literacy in relation to water. Openness or resistance to these two concepts is significantly influenced by the prior experiences, and the conscious or unconscious ideologies of the teacher and the student. The idea of exploring scientific literacy in relation to water may be dismissed by some as a radical teacher trying to advancing their social or environmental justice agenda, and others could view generating water literacy as falling in line with the expected hegemonic agenda in order to be view as successful with the educational system. Both are valid educational agendas, and both have political underpinnings and implications for water education in Australia. The question becomes not which of these agendas should science education align with, but rather in what ways can science teachers look beyond all of our cultural norms, agendas and assumptions and raise questions that open the limits of knowledge and encourages students to question assumptions about what is, and has been, considered 'normal'. Teaching students to look beyond what any of us take for granted helps us explore new possibilities for understanding water and its immeasurable contribution to our planet and our lives.

8. Conclusion

The beginning of this article highlighted expectations of what it means to be scientifically literate in relation to water and what it means to be water literate. These two concepts were shown to be underpinned by different ideologies. The ACS was then investigated for references to concepts associated with water. As there is little research in Australia about [future] teacher's comfort in teaching concepts and issues associated with water, the results of a small study of pre-service teachers comfort levels were presented. The results illustrate that both the ACS and the pre-service teachers align with generating water literacy. Less focus and comfort are shown towards concepts associated with generating scientific literacy in relation to water.

The analysis suggests that the question arising for water education in Australia is not whether the ACS or [future] teachers should be addressing issues associated with water, but rather how and to what end goal. This necessitates raising questions about the partial and political nature of any approach to educating about water, and highlights that not all approaches are equally as politically neutral or challenging.

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