

SCIENTIFIC LITERACY FOR SUSTAINABILITY

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STATEMENT OF AUTHORSHIP

This is to certify that

- (i) the thesis comprises only my original work towards the PhD;**
- (ii) due acknowledgement has been made in the text to all other material used; and**
- (iii) the thesis is approximately 80 000 words in length.**

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ABSTRACT

We only need to consider public media reports to appreciate that there is growing concern amongst citizens for sustainability. This concern arises from increasing appreciation that the current direction and rate of exploitation of resources is not sustainable and humanity's actions today are arguably compromising future generations' ability to meet their living needs. By drawing on the research of scientists, ranging from their evidence of the problems of sustainability to those promising solutions, the same press reports show strong links between sustainability and science. The appearance of such reports in the public media implies that citizens understand the interaction of science and sustainability and that they can engage critically with scientific research, including its applications and implications for sustainability. In this dissertation this understanding and capacity to engage critically is termed *scientific literacy*. The general question governing the research reported in this dissertation arose from this context and is: What does it mean for citizens to be scientifically literate within the context of sustainability? More specifically, because it is expected that university graduates are well educated in a socially relevant manner, with commensurate responsibilities and influence, the focus question studied in this dissertation is: What does it mean for university graduates to be scientifically literate?

It became apparent from the review of the literature, that the concept of scientific literacy was multidimensional. The three key dimensions that emerged were (i) the fundamental and enduring ideas and concepts of science, (ii) the nature of science and (iii) the interaction of science with society. These dimensions provided the framework for the research reported in this dissertation. Within this framework and based on the literature, two relationships amongst these dimensions were proposed. The first

relationship was that the dimensions were in a conceptual hierarchical order, with successive dimensions including the previous dimensions and expanding upon them. The second relationship was that students' scientific literacy developed sequentially along the same hierarchy. It was proposed that development occurred sequentially, with development of concepts of science first, nature of science second and interaction with society last. It was proposed that a scientifically literate person would have reached the level of understanding that includes the interaction of science with society. Specific indicators of the successive dimensions were functional, conceptual/procedural and multidimensional, which at this highest level, includes the relationship between the first two dimensions and society.

This framework and the associated indicators were used as a structure and lens for interrogating the development of scientific literacy of 244 first year university students enrolled in Australia's Murdoch University's foundation unit, *Life and the Universe*. This is one of five units from which first year students are required to select one. The units are interdisciplinary in nature with *Life and the Universe* being a unit that covers generic issues in science. In part because of its content and in part because it allows students from all backgrounds to enrol, it was considered suitable for studying, illustratively, the development of scientific literacy of potential university graduates.

The development of scientific literacy was studied in three ways. First, participants responded to open questions about a newspaper report of science, before and after their studying in *Life and the Universe*, second, they responded to a Likert style questionnaire regarding the nature of science, again before and after studying the unit, and third, a subset of participants were involved in a focus group run over two years.

The participants' responses to the open questions on the questionnaire were analysed for their critical engagement with the news brief, in terms of their ability to give reasons why the text should be accepted or rejected. The nature of requests for extra information about the news brief's content was also analysed. Analysis of the initial responses to the open questions showed that more than fifty percent of the participants in this study did not demonstrate the ability to critically engage with science reported in the news.

The Likert style questionnaire assessed participants' conception of the nature of science, with one end of the continuum reflecting a traditional view that science was a body of unchanging facts, derived from objective and value free observations, and the other reflecting a more contemporary view, that scientific knowledge was dynamic, open to change, had subjective components, and had scientists socially located so that their work was not free of values. Analysis of the initial responses to the Nature of Science questionnaire showed that more than fifty percent of the participants were located on the continuum towards the contemporary, socially located end. However, it also showed that the majority were still not sufficiently located towards the contemporary end of the continuum to view science as dynamic, with a changing body of knowledge. There was no statistically significant difference in these analyses in relation to participants' gender, time out of school, course of enrolment or science background.

Unexpectedly, the comparison in the analysis of the news brief pre and post *Life and the Universe* showed that the number of participants engaging critically did not increase. More expectedly, the comparison of the pre and post *Life and the Universe* responses to the Likert scale showed that there was overall a statistically significant increase in the group's contemporary, socially located, perspective of the nature of science during their participation in the foundation unit. Specifically, the participants demonstrated raised

awareness of the tentative and subjective nature of science and that scientists study a world in which they are a part and, as such, their work is not objective or value free. Nevertheless, there was substantial possibility of higher locations on the scale which the majority of participants did not reach. This statistically significant increase, but possibility for further improvement, is compatible with the lack of increase in critical engagement with the news brief and suggests that the statistical increase was not educationally significant.

The focus group data contributed greater depth of understanding to the researcher about the range in participants' conceptions of the nature of science. The conceptions evident were consistent with the conclusions from the open questions and Likert style questionnaire and also highlighted limited understandings of scientific processes or scientific methods. It was evident that misconceptions and naïve understandings of the contemporary nature of science were present at the beginning and retained throughout the foundation unit learning experience. These limitations helped explain participants' inability to engage meaningfully and to question critically the science news briefs contained in the questionnaires. Data from the focus group also suggested that a limited understanding of science terms prevented critical engagement with the content of the news briefs.

Following closely the focus group participants' development of scientific literacy over a two year period, allowed the researcher to gain a greater depth of understanding of the participants' development of scientific literacy than that which could be gained alone from the large scale administrations of the questionnaire. This experience highlighted that the development of scientific literacy was far more complex than the originally proposed sequential development across the three dimensions. The analysis of

converging sources of data challenged this proposition and resulted in a reconstruction of understanding about the development of scientific literacy. It was evident that the ability and disposition to critically question and act scientifically required parallel development of science content, socially located conceptions of the nature of science and understanding of its interaction with society. It was the blended and parallel development of these knowledge dimensions, at any level, that demonstrated scientific literacy.

In order to characterise the more complex structure amongst the dimensions in which parallel development occurred, a rope metaphor was used. This metaphor effectively represented the observed development of scientific literacy, as it made concrete the interwoven threads of multidimensional knowledge. It represented more realistically the complex, intertwining and multidimensional aspects of participants' development of scientific literacy. Re-thinking the development of scientific literacy and representing the construct with the rope metaphor offered possibilities for effective pedagogy in higher education. The interaction of multidimensional threads of knowledge seems an integral part of the development of scientific literacy and suggests the need for teaching and learning experiences that are holistic in nature and driven by socially relevant contexts.

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