ACHIEVING SCIENTIFIC SUSTAINABILITY – A PILOT STUDY INTO THE IMPORTANCE OF IMPROVING FIRST YEAR UNDERGRADUATE SCIENTIFIC LITERACY IN THE BIOLOGICAL SCIENCES

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ABSTRACT
Although there have been many attempts internationally for reforming the way in which science is both seen and taught at a variety of educational stages, there appears to have been very little movement in Australia with regard to scientific literacy in education (especially at the first year undergraduate level). Through the development of a 10-item multiple choice test which examines biological scientific literacy, an analysis was made from (a) a large core biology class using traditional methods, (b) a small elective biology class using less traditional and more innovative methods, (c) a first year education class with no science instruction, and (d) members of the general public. It was predicted that students in the science elective class would show more biology scientific literacy because of more innovative teaching methods and with a focus on this area. We also predicted that both science classes would show more biology scientific literacy than the education class, which in turn would show more than the general public. However, some unexpected patterns emerged essentially: core > public > elective > education.

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INTRODUCTION
Often, when the words ‘scientific literacy’ are mentioned, it usually implies that a particular principle group (teachers, students, or even scientists themselves) is going to be reprimanded for their lack of scientific understanding on a range of issues (Paisley, 1998). The notion of a severe lack of science knowledge within the Australian population is considered to be highly alarming as, as claimed by Rennie (2005), scientific literacy should be considered to be a high priority for all citizens as not only does it increase their interest in and understanding of the world around them, but allows them to engage in discussions of scientific advancements and be sceptical and questioning of claims made by others. However, the observed negative reaction towards science, especially by students, is largely due to the commonly held perception that science is too difficult, requires copious amounts of background knowledge, and that science is altogether ‘too boring’ (Burke da Silva, 2008), (often resulting in the avoidance of science based topics at most levels of schooling – including tertiary and other higher education options). This, then, raises another concern as, listed amongst the graduate qualities of most, if not all, Australian universities is that of students being ‘knowledgeable’ with a further understanding of how that knowledge can then be applied to real world contexts. As all university graduates, both national and international, are our potential future leaders, a reduced level of scientific literacy is considered to be an issue of high importance, as without at least a basic understanding of the nature of science, graduates may soon become disadvantaged in our increasingly technological global environment (Burke da Silva, 2008; Laugksch, 2000).

In comparison to other countries such as Finland, China and Canada (Thomson et al, 2006), Australia is considered to be rapidly losing ground when it comes to graduate scientific literacy, now ranking 9th out of the 30 OECD (Organisation for Economic Cooperation and Development) countries for the proportion of the population aged 25-34 with recognisable tertiary qualifications (Commonwealth of Australia, 2008); and 20th out of the countries which produce graduates with degrees in science and engineering (FASTS, 2010). This is particularly worrying when the demand for technically and scientifically literate people in the Australian workforce far exceeds the level of supply at a rate of 3.5% per year (FASTS, 2010). Yet, even with these statistics and the knowledge that the number of students which study science, technology, engineering and mathematic (STEM) topics has either remained static or fallen sharply, ‘such a decline seems counter intuitive in the context of the technology revolution that has taken place over the same period' (Rice, Thomas, & O'Toole, 2009 p.12). It is believed that in order to reduce the impacts associated with such a decline in numbers from within science based courses, there is a need to not only attract students, but for those who do, to remain engaged with their course through the use of innovative teaching pedagogies (Burke da Silva, 2008; DeHaan, 2005).

Though the need for students to achieve scientific literacy has become well accepted by many educators (Rennie, 2005), many university faculties still rely on the usage of 'traditional' lectures due to the appeal of a convenient and cost effective manner in which to provide a 'liberal' education to hundreds of students at any given time through a common lecture, laboratory and tutorial format (Wyckoff, 2001). However, this method is often still based on the outdated transition model of teaching and learning (King, 1994). According to Seymour and Hewitt (1997), the use of this lecturing style has lead to almost half of the original number of students that do enrol into these large lecture based courses to withdraw within two years due to perceived attempts by academics to 'weed out' the next generation of scientists (DeHaan, 2005; Wieman, 2007). King (1994) indicates that continued usage of this model will no longer increase the number of science students, as students are often known to complain about the compulsory memorisation of isolated facts and figures in these types of courses and that they also provide "little opportunity for conceptual development and test little more than students' abilities to remember" (DeHaan, 205 p.254).

Fortunately, there has been some movement within Australia and from around the world by educators which aims to address these problems, primarily in the form of changing the way in which science is both seen and taught. The main way in which this has been addressed is by imploring organisations and curriculum developers to remedy the issue by teaching science in the way that it is practiced (through investigation) so that students may have a better understanding of critical concepts (McWilliams, Poronnik, & Taylor, 2008; DeHaan, 2005). Interestingly, at the first year undergraduate level, there have been few studies into the area of achieving scientific literacy, and of those that do exist, many deal with either physics or chemistry. In order to address the lack of information for other science subjects, this investigation primarily focuses on biology, as there is little evidence to support whether core or elective topics within this field can improve scientific literacy (or if they are at all valuable in resolving misconceptions of current socio-scientific issues).

Using a survey tool, developed to determine the level of understanding and knowledge on current biological societal issues, a series of ten multiple choice questions were asked of first year undergraduates from Flinders University of South Australia, as well as members of the general public within the city of Adelaide. The survey is such that it could also be easily modified to suit other science courses within Australia and international universities; however, this study will evaluate whether current methods of teaching and learning at Flinders University are having their intended effect (i.e. whether current practices are imparting students with factual knowledge only or if they also provide them with the skills needed to interpret the critical issues which affect them on a daily basis – essentially scientific literacy). This information will then hopefully provide useful data in order to apply more innovative teaching and learning practices across Australian universities if not done so already, and highlight the importance of achieving scientific literacy nationally.

Consequently, the principle aims of this investigation are:

- To observe if there is a significant difference in the level of scientific literacy between non science students who do not take a science elective and non science students that do take a science elective
- To investigate if different methods of teaching scientific literacy (i.e. innovative versus traditional methods) plays a role in changing students' misconceptions of science
- To consider if there is a significant difference between the proportion of members of the general public that have studied science at either a high school or university level to those that have not and if this then affects their level of scientific literacy

METHODOLOGY

As science pervades nearly all aspects of modern society, it has become crucial that all citizens develop the ability to consider, make decisions on, or resolve current socio-scientific issues (Sadler, 2004). Supporting evidence for this is especially highlighted in the constant bombardment of political and media campaigns to the general public on issues such as cloning, global warming and genetically modified food. The ability to critically analyse the validity of a given argument, or media presentation, in order to come to a logical conclusion regarding such an issues, should thus also be considered to be highly valuable in terms of graduate qualities. This type of decision making requires that all individuals possess at least a basic understanding of the science which underlies the issue, or the ability to acquire such information (Rennie, 2005; Sadler, 2004).

In Australian universities, the level of diversity and the number of students seen in recent years has created an increasing gap between university assumptions about students and students' expectations of university (especially in regard to previous scientific knowledge requirements). The wideness of this gap is critically important as students' experiences of science within their first year of university can significantly affect their future academic success in similar topics and their perseverance throughout the rest of their degree (Flinders University, 2011a).

In designing this project, it was determined that a focus on first year biology and education courses would allow for a sufficient sample of the student population to be examined, as this is where the student body is at its most diverse and not too far removed from previous schooling (Rice et al, 2009). Due to this expectation, and for the purposes of this investigation, 'scientific literacy' (in a biological sense) was thus defined to refer to the ability of both students and members of the general public to be able to understand the major concepts within the field of biology, communicate effectively about biological issues to promote further understanding, and the use of inquiry to address any current societal misconceptions they may have (Ebert-May, Brewer, & Allred, 1997). This focussed effort on introductory biology, and education in particular, highlights the large number of science majors and non majors whose scientific and biological literacy are in need of improvement as traditional classes in these fields tend to reinforce students' roles as passive learners (Ebert-May et al, 1997).

Though not a new concept, learning science at any level is considered to b a practical process that requires active participation in order to gain a more thorough understanding. For the retainment of numbers and interest within science based courses, it is obvious that the concepts and activities that are carried out within smaller groups sessions, such as tutorials, needs to be also applied to larger lectures.

Although still in their infancy, the improvements in the quality of teaching and the use of innovative pedagogical approaches can significantly influence students' attitudes towards science and thus improve their scientific literacy in general. The core first year biology program 'Molecular Basis of Life', and the elective 'Biology and Society' at Flinders University, in particular, strive to engage students and to provide them with the tools needed to increase their scientific literacy and general understanding of science.

BIOL1102 – MOLECULAR BASIS OF LIFE

Composed as a series of integrated lecture and laboratory sessions, the 'Molecular Basis of Life' is the largest first year core biology topic at Flinders University (often serving as a prerequisite for many other second year topics). With approximately 600 students taking this course each year, emphasis is placed on students being able to gain a basic understanding of a range of topics including biochemistry, the nature of genetic material (such as its replication and expression), the function of intracellular organelles and the evolution of organisms from single cells to mutlicelluar beings (Flinders University, 2011b). Seen to be more of traditional science topic (in that this subject utilises the more common lecture, tutorial and laboratory format), the topic is typically taught as a large lecture based course with three classes per week which employs multiple instructors throughout the course to provide in depth case studies into individual sections that usually reflect their research interests. Yet, similarly to other science topics at a university level, 'for individuals committed to being science specialists, the traditional method of teaching has its uses and rewards. However, to reach the larger audience of students with non-science career goals, a more flexible pedagogy needs o be considered...one in which the humanistic and societal issues of science are examined along with the facts of science' (Duschl, 1988 p.51).

BIOL1112 – BIOLOGY AND SOCIETY

Similar to one of the most significant and sustained international elementary school curricular movements (Science, Technology and Science (STS)), 'Biology and Society' allow students to 'explore the relation between science, technology and society by focussing on real life issues that involve these domains' (Sadler, 2004 p.43). Redesigned in 2006, this subject specifically aims to improve scientific literacy by providing students with an opportunity to develop their critical thinking and problem solving skills (Flinders University, 2011c) by presenting students with issues currently being debated within the community through the use of a mixture of both theme based lectures and in class discussions (Burke Da Silva, 2008).

EDUC1120 – TEACHING AND EDUCATIONAL CONTEXTS
With education often being considered to encompass the range of settings from early childhood through to tertiary education, this topic was also selected for investigation as it is the largest non science first year undergraduate topic at Flinders University and acknowledges the historical and political aspects of both education and teaching (Flinders University, 2011d). Often, after the completion of an undergraduate degree, students who were classified as non science majors at university are often called upon in the education sector to teach a significant fraction of science principles and concepts in a variety of school settings where their experiences of science at university (which may only be a single semester in most cases) will then shape not only their attitudes towards science, but of those whom they teach (Kirkup, Scott, & Sharma, 2007). It was therefore deemed particularly important to investigate what the current level of scientific literacy is among these students in order to prevent misconceptions forming.

MEMBERS OF THE GENERAL PUBLIC OF ADELAIDE
The advances made in both science and technology is widely known by all members of the community to play crucial roles in our modern day society; and it is often believed that the greater the level of understanding the public possesses, the more positive their attitudes toward science will become (Evans & Durrant, 1995). For most members of the general public of Adelaide, and indeed everywhere, the ability to get involved with current societal issues relies heavily upon the possession of critical thinking skills and the knowledge of enough (or where to find enough) information (Rennie, 2005), as, central to any decision making process is the critical examination of all relevant knowledge involved (Bingle & Gaskell, 1994). Yet, there is much controversy as to how to measure scientific literacy levels to effectively gain an insight into how much understanding people possess and how they are able to sufficiently weigh up the risks and benefits of many scientific issues.

Table 1: Number of Survey Respondents Sampled during May to June 2011 for each Experimental Group

Experimental Group	Number of Respondents
BIOL1102 – Molecular Basis of Life	191
BIOL1112 – Biology and Society	25
EDUC1120 – Teaching and Educational Contexts	51
General Public of Adelaide	150

SURVEY DESIGN
The literature surrounding the numerous ways in which to examine scientific literacy is full of studies which aim to identify the range of students' misconceptions in relation to particular scientific topics, with three particular styles of questioning most commonly used: open-ended, true-false, and multiple choice (Tamir, 1999). In many studies, the use of open-ended questions has been shown to provide a better measure of understanding than those with closed ends; however, it is often observed that these then allow for too much data to be collected (most of which id the often deemed to be of no importance to the study being undertaken) (Brossard & Shanahan, 2006). On the opposite end of the scale, the true-false format, most commonly used in scientific knowledge related studies, does not provide enough information for a sufficient analysis as respondents can have a fifty percent chance of selecting correctly out of a choice of two answers (Brossard, et al, 2006). Because of these reasons, it was then decided that for the purposes of this investigation that a separate and new multiple choice survey would e developed based on a range of first year textbooks.

Although multiple choice questions are often criticised for enhancing negative educational outcomes, such as rote learning, the benefits of their use is that they are relatively easy to develop, are able to cover a wide range of topics in a short time frame, their scoring is both easy and objective, and 'they avoid unjustified penalties to students who know their subject matter but are poor writers' (Tamir, 1999, p.188). To maintain a reasonable level of cognitive ability, the focus of the selected questions was turned away from correct versus incorrect to the selection of the 'best' answer for the respondent (with the distracters being common misconceptions of the topic being answered). This was done in order to present the respondent with the task of analysing the various available options before selecting an answer that they felt best answered the question. By using this technique, it was then expected that the results would quickly indicate not only how many respondents chose a particular answer, but also the most common misconception. In a teaching and learning context, this information provides essential feedback to science educators as 'if most students in the class are not sure about a particular item, the teacher may consider that there is a need to revisit the relevant subject matter in class' (Tamir, 1999, p.189).

DATA COLLECTION

As it is difficult to collect data from every intended individual, a sample of each research population was taken by selecting those respondents who were most willing to complete the survey through a verbal agreement with the primary researchers (Sarah Illingworth) before surveys were then distributed. For students, result were obtained by distributing surveys during lectures (once topic coordinator and lecturer permission had been obtained) throughout the period of May to August 2011; whereas members of the general public were approached in locations such as Rundle Mall (in Adelaide due to the expectation of a wide diversity of respondents within these areas.

A personal approach was deemed to be best for the aims of this investigation, as respondents were able to discover more about the aims and nature of the research and have a person to ask if they were unsure of what was expected of them in regard to answering the questions. Because of the concerns regarding identity when completing surveys, no personal information was asked of respondents, except in the case of students where only their student identification number was asked of them in order to prevent double sampling. All surveys were returned immediately upon completion to the primary researcher to prevent issues regarding confidentiality from arising, and only the primary researcher was involved in the analysis of the results.

DATA ANALYSIS

Upon each survey's completion, the total scores (out of 10) for all respondents were entered into a Microsoft Excel spreadsheet in order to examine the level of scientific literacy for each experimental group. The use of a scale that ranged from 0 to 10 was deemed to be the most appropriate as it clearly indicated a 'severe' lack of scientific literacy (0) to a 'sufficient' level of scientific literacy (10). Although 23 students had been indicated to study both the core topic 'Molecular Basis of Life' and the elective 'Biology and Society', of these students that participated in the investigation as respondents, only one of their surveys was counted so that their answers still made a contribution to the study. Questions were analysed individually across all groups, before the mean and standard deviation of each experimental group was determined in order to utilise an unpaired t-test to investigate levels of significance between individual sets of data.

RESULTS

When questions were analysed independently, it was found that all groups answered Question 4 (Evolution and age of living organisms) with the highest correct responses coming from the two Biology courses, with a score of BIOL 1102 (88%) non-science, BIOL 1112 (92%), EDUC 1120 (69%), and public (66%). With respect to questions answered incorrectly most often, students from both Biology topics answered Question 8 (common cold) incorrectly most often (BIOL 1102 76%, BIOL 1112 79%), whereas education students answered Question 6 (Bioremediation) incorrectly most often (92%), and the general public answering Question 3 extraterrestrial life most incorrectly (47%).

Also shown in Table 2 students in the core biology course had the highest mean scientific literacy score compared to non-science students in the elective biology course and non-science students in education course who were not taking any university science courses. Interestingly, the public scored reasonably highly with a mean score only slightly lower than the core biology students. When the general public sample was investigated more closely, it was found that of the 150 respondents, 45% had completed some level of tertiary qualification, while 55% had not. When compared these two groups did not show a high level of significant difference between the level of scientific literacy (P= 0.0833).

A comparison of the mean level of scientific literacy of core Biology students with Education students revealed a highly significant statistical difference (T=6.02, P<0.0001). A highly significant difference (P=0.0001) in the level of scientific literacy was also observed between students taking the elective science course BIOL1112 and the core science course BIOL 1102 (t=-3.93, P<0.0001), but the low numbers of student responses in BIOL 1112 make this finding less reliable. We did not find a significant difference in the level of overall scientific literacy between non science students (EDUC 1120) who did not take a science elective (n=51) and non-science students that took a science course, BIOL 1112 (n=24), (p=0.63). Although the mean values for students from BIOL 1112 were higher on average, the low number of students sampled may have contributed to the lack of an overall statistically significant different.

The general public scored significantly less well than the core science students (BIOL 1102 at t=-3.78, P<0.01) but scored significantly higher than EDUC 1120 students (t=2.28, p<0.02).

Table 2: Calculated Mean and Standard Deviation for Each Survey Question Answered Correctly across all Experimental Groups

		Number of Correct Answers					
Question	Topic	Core	Elective	Education	Public	Mean	STDEV
1	Human Cloning	47%	54%	43%	48%	49.8	38.3
2	Climate Change	43%	38%	43%	50%	47.5	37.5
3	Extraterrestrial Life	47%	42%	45%	37%	45.0	36.3
4	Evolution	88%	92%	69%	66%	81.5	67.9
5	Science and Technology	78%	58%	62%	65%	74.0	63.3
6	Bioremediation	45%	29%	8%	29%	35.8	39.3
7	Human Genome Project	70%	67%	39%	55%	63.5	57.0
8	Common Colds	26%	21%	25%	42%	33.0	28.3
9	Nature Reserves	37%	13%	31%	33%	35.3	31.5
10	GM Food	77%	88%	35%	37%	60.8	61.2
	Group Mean	5.54	4.11	3.87	4.63		
	Group STDEV	1.71	2.31	2.05	1.96		

Other alternative explanations of the pattern of the findings, may include whether students had entered each course directly from high school or not, and if they had studied science during their previous education experiences. On further examination of the data collected, it was noted that 88% of the students in BIOL1112 reported that they had studied science at high school at some stages and that 79% of the total respondents had entered directly from high school (compared to 63% of BIOL1102 students studying science at some stage in their high school education, and 88% enrolling into university study directly from high school). A possible implication of this is that there may have been a higher tertiary entrance score for the students undertaking the core course than for the elective course that may have produced the higher result. When these numbers for each course ere compared to one another in order to test for significance, it was observed that there was a high level of difference between the number of students who had studied a high school science course (P=0.0011) as well as those that had enrolled directly from high school (P=0.0149).

DISCUSSION

It was originally predicted that the use of the more commonly accepted ‘traditional’ methods for teaching in large, lecture based science courses would be less effective in providing scientific literacy to students when they were compared to more innovative practices, such as those that were observed in the elective BIOL1112 (‘Biology and Society’). This investigation, however, noticed that this was not the case, as students who had enrolled in the core science course BIOL 1102 scored significantly better than any of the other courses surveyed.

Whether this indicates that a more traditional approach was important in this finding, or simply that core science students are either exposed to more information that may help them answer the questions more correctly, or that they read more outside of their courses (ie. Greater interest) in this area remains unknown, and as a result should also be questioned about if the survey were to be readministered in addition to prior exposure to biological issues, previous education in the biological sciences and interest levels.

The lack of a significant difference in the level of overall scientific literacy between non science students who did not take a science elective (EDUC1120) to those that did (BIOL1112) was surprising and as pointed out, requires more data to be collected in order to determine whether this finding will hold.

Interestingly, the most correctly answered question across all groups was based on the topic of evolution. This question upon closer examination does not require understanding of the general concept of evolution rather an understanding of the age of the earth and the timing of when life began. As the survey was administered later on during the university's semester one of teaching, the topic of the age of the Earth is likely to have been covered earlier in both science courses – potentially leading to a slight bias in the results. In order to reduce this effect in any future investigation, it is recommended that the survey be distributed at the very start of semester before subject matter has begun to be covered. It is also interesting that this topic was considered by many of the participants to be more geology based rather than an actual example of biological evolution (such as that covered by natural selection), and therefore was considered to be an inconsistency within the survey. This notion may have then possibly led to the interesting observation that some students from BIOL1112 did answer some of the questions much better than the EDUC1120 students. This may have been an indication that in areas where certain issues were covered, the students from BIOL1112 may have had a far better understanding, but as not all items listed on the survey were covered in the course, overall literacy differences were not observed to show up more strongly. Because of these 'flaws', it is recommended that the survey be distributed at the beginning and end of the teaching term in order to gain a true insight as to how much scientific literacy is obtained over the course of a semester and if this is significant across each of the experimental groups.

Interestingly, the general public scored reasonably well in overall scientific literacy (better than the non-science students but less well than the core science students). However, further examination of this data is required to investigate whether the university education population or public have an interest in science, which may influence their scores, or are gaining scientific literacy through independent avenues other than tertiary education.

The findings of this paper indicate that students in a core Biology course have the highest level of scientific literacy, and that non-science students have a far lower overall scientific literacy score. Further analysis needs to be undertaken to determine whether a science elective topic potentially made relevant to all courses would be effective in increasing scientific literacy in Australian universities and if so what would be the most effective teaching strategies in order to achieve this.

CONCLUSION

This pilot study enabled the researchers to 'test the water' to understand what the current level of scientific literacy is amongst both first year undergraduate students at Flinders University and members of the general public of Adelaide.

A much larger study with greater numbers of respondents and more analysis into the reliability and validity of the survey used in this investigation will be needed to examine if there is a potential requirement for all undergraduate students to participate in science related courses to increase their scientific literacy.

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