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Reconstructing the relationship between science and education for sustainability: A proposed framework of learning

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Science and education for sustainability have recently become estranged. Both of these learning areas are also experiencing issues that are affecting students' understandings in these areas. This paper presents a framework of learning containing 12 components that reconstructs the relationship between these two areas and could have the potential to overcome their current issues. A 15 week science/education for sustainability programme that was undertaken by 22 New Zealand students aged 11-12 years was analysed in terms of the components of the proposed framework. An interpretive analysis of the learning that took place showed beneficial effects on students' understandings. Not only did these students demonstrate understandings of sustainability and development of their scientific literacy, they also showed an emerging politicisation in that they were able to take action on an issue in a number of ways. It was also suggested that further components could be added to the proposed framework in order to develop additional knowledge and skills that could enable students to gain a deeper understanding of and ability to make decisions about the multifaceted environmental issues found in today's world.

Key Words: Science education; education for sustainability; children's learning

Reconstructing the Relationship between Science and Education for Sustainability: A Proposed Framework for Learning

Even though part of education for sustainability's foundations were located in science education, since the 1990s these two areas of learning have grown apart (Gough, 2007). Recently there has even been argument that science education is not needed in education for sustainability [EfS] programmes (Tsevreni, 2011). This paper argues that there is a need to reconstruct the relationship between science education and EfS in order to facilitate the type of learning needed by young people who live in a world where an understanding of complex environmental issues is needed. However, in order to gain maximum benefit from this amalgamation, this paper asserts that a different approach to learning when studying an environmental issue needs to be employed.

Firstly this paper will discuss the approach to science education required for such a reconstruction. Then the advantages of a reconstruction of the relationship between science and education for sustainability will be outlined. A framework of learning that represents the reconstruction of this relationship will then be put forward. A classroom programme using this proposed reconstruction will then be analysed using the proposed framework.

Towards a Different Approach to Science Education

There is no doubt that education for tomorrow's citizens must include science. Science is an important part of a person's education because it is seen by the public as powerful and authoritative as it shapes people's lives and the development of societies (Kim, 2011). Science education is also essential because science occupies a central place in today's knowledge-based societies since science knowledge, together with technology, are now able to bring about enormous transformations to Earth's natural systems in an unprecedented way (Colucci-Gray, Camino, Barbiero & Gray, 2006). For example, scientific and technological knowledge now enable people to travel distances on aeroplanes at faster speeds and at a cheaper cost, accelerating the rate at which business negotiations can take place, and even allowing people to use aeroplanes for commuting between countries. However, this increased use also brings with it the potential for pandemics, such as swine flu, the use of dwindling oil supplies and increased greenhouse emissions (Levinson, 2010).

At this point, it is important to discuss the relationship between science and technology. There has always been a close collaboration between the two (Bensaude-Vincent; Loeve, Nordmann, & Schwarz, 2011). However, over the last twenty-five years, the distinction between these two fields of endeavour has become blurred as both science and technology are being used to bring about innovations, often in association with private enterprise (Colucci-Gray, Perazzone, Dodman & Camino, 2012). This blurring has also given rise to new amalgams of science and technology such as bioinformatics (Levinson, 2010). As a result of this blurring, the term 'technoscience' has been coined to represent the fusion of science and technology (Bensaude-Vincent et al.) and recognises that scientific knowledge is developed in response to societal, political, technological and economic concerns (Levinson). As a consequence, many issues facing contemporary society involve both science and technology, for example the production and distribution of food which involves monocultures that require pesticides and artificial fertilisers along with the use of fuels to harvest and transport food into cities and the consequent greenhouse gas emissions. Therefore, when using the term 'science' in this paper, it is acknowledged that there is this interrelationship between science and technology although it has not been made overt.

There is a problem with science and it could be in the public's perception of scientific knowledge and scientists. Despite science occupying a position of cultural dominance, referred to as "scientific imperialism" (Tsevreni, 2011, p. 55), and being the powerhouse of civilisation (Ravetz, 2004), the public tends to be distrustful of science (Levinson, 2010). Although science is viewed as the "ultimate authority" (Ashley, 2000, p. 271), over the past 50 years public confidence in science has dwindled as was illustrated by the public protests against the release of genetically modified organisms in New Zealand (France, 2011). Despite the way that scientific knowledge has resulted in innumerable benefits for people, such as increased longevity, these benefits have given rise to concern and even apprehension about their potential hazards (Levinson). For example, while nuclear reactors are able to supply people with electricity that does not involve the release of greenhouse gases or large-scale alteration of landscapes as is the case with hydro-electricity, there is still the potential danger of managing radioactive waste in the event of a nuclear accident.

Furthermore, science is often cast in the "role of the villain" (Hodson, 2003, p.649) when these environmental tragedies do occur, further eroding public confidence. For example, the use of DDT was banned worldwide in the 1970s because of its perceived detrimental effects. According to Harrison (1978) and Mellanby (1992), the ban was the result of media campaigns and litigation that took advantage of public naivety about DDT's environmental effects. Not only were the media campaigns based on exaggerated accounts of DDT's toxicity, but because the public were more familiar with DDT given its earlier widely reported successes, they mistakenly attributed the effects of more toxic pesticides such as 2, 4-D and maleic hydrazide to DDT usage. Thus DDT, as a product of science, was tarred with the same brush as the more toxic pesticides and till recently, its use banned.

One reason for this lack of public confidence in science is that the public are "anti-science" (Littledyke, 2008) and hold a naïve view of it (Ashley, 2000). Instead of being able to make informed decisions about complex socioscientific issues such as finding out what type of personal actions to take to mitigate the effects of global warming, they rely on politicians for guidance who are in turn reliant on the advice of scientific experts. In this way, the public is forced into a paternalistic relationship with politicians and scientists and are unable to engage in debate about evolving scientific knowledge or contribute effectively to decision-making in democratic societies (Ashley). According to Ravetz (2004), this lack of ability to make informed decisions is not desirable because a free society needs public participation and should not rely solely on the contribution of experts.

Science education is seen as fundamental to solving this problem of the public's naïve understandings and perceptions of science. The central goal of science education is viewed by many as *scientific literacy* which aims to develop "well-informed, good citizen[s]" (Lee & Roth, 2003, p. 403) who are able to engage in debate about scientific issues and take an informed personal position. Although exactly what scientific literacy should entail is both problematic and the subject of debate (Hodson, 2003; Millar, 2006), there is agreement that being scientifically literate should involve three aspects: understanding about the nature of science; being aware of the way that science and society interact; and knowing important scientific concepts (Skamp, 2009). Being scientifically literate also involves being able to critique the work of scientists. This general understanding of scientific literacy acknowledges that the majority of students will not become scientists, who are the *producers* of scientific knowledge. Instead they will become citizens in a society where they are *consumers* of science, needing to be able to make intelligent and informed decisions about socioscientific issues in their lives (Millar, 2006) and be able to make changes to society if needed. When science education is viewed in this way, it has the potential to assist people to acquire knowledge so that they can "develop effective solutions to its global and local problems" and also encourage an "intelligent respect for nature that should inform decisions on the uses of technology" (AAAS, 1989, p. 12). Moreover, developing scientific literacy through formal education could also result in a more active scientific community where they could see the purpose in informed citizen debate (van Eijck & Roth, 2007). Consequently, development of both the scientific community's and the public's scientific literacy could then lead to a partnership where solutions for socioscientific issues could be found together.

However, scientific, or any type of literacy is more than decoding and encoding print. Being literate has a far wider connotation in that it relates to the notion that language is a system of socially constructed signs, rather than being representative of reality (Stables & Bishop, 2001). Colucci-Grey et al. (2012) go further, arguing that language reflects the embodiment of the way in which people perceive their world – it is an expression of how they view, sense and see their 'place' in the world. Norris and Phillips (2003) concur with this view of literacy and argue that a wider conception of literacy is needed because the majority of people gain their information about scientific issues through text and scientific literacy cannot be achieved by being able to read scientific material and information by knowing the words, locating information and recalling content. Norris and Phillips assert that the ability to paraphrase, critique and summarise scientific material is also insufficient. They argue that when reading and writing scientific material, students need to have an understanding that the text has been created by a person; that it is an artifact that can be analysed and evaluated in terms of its author's expressions of doubt or certainty about scientific statements. For example, students reading scientific text need to be able to distinguish between observations and scientific statements, understand the account of the methods followed, differentiate between doubt and conjecture and identify the reasoning used to make scientific statements. These skills and understandings are referred to as the "conceptual relations" that are intertwined into scientific material that is well-written (Norris & Phillips, p. 234). Furthermore, they extend their conception of literacy to include media such as television and newspapers as many people use these sources to access scientific information. Therefore, according to these authors, scientific literacy needs to be extended to include literacy in a broader sense so that people can understand these conceptual relations found within scientific material.

While the goal of scientific literacy is included in science curriculum documents, there is an issue with many people's epistemological view of science. Many people, including teachers, hold an epistemological view of science that can be regarded as modernist and this type of view can affect the development of scientific literacy (Littledyke, 2008). A modernist view of science has its roots in the Enlightenment's scientific revolution. This view has a reductionist tradition which focuses on how individual parts of a system function. This view involves searching for linear relationships of cause and effect at a micro-level in order to make changes at the macro-level, while ignoring the complex functioning of a system as a whole. This view of science is also considered mechanistic, objective, values-free and largely makes claims of absolute truth (Colucci-Gray et al., 2006, Littledyke, Ravetz, 2004).

For some science educators, this modernist view of science has been replaced by a post-modern view or what Funtowicz and Ravetz (1993) call post-normal science. Ziman (2000) refers to this view of science as post-academic. A post-normal or post-academic view rejects the idea of science being values-free, objective and providing absolute truth. Instead science knowledge is recognised as being dependent upon the culture in which it is constructed (Littledyke, 2008). It also recognizes that the construction of scientific knowledge is affected by the political and economic institutions that fund scientific research, resulting in some scientists losing their autonomy over their research (Ravetz, 2004; Ziman, 2000). Furthermore, neurophysiology findings have shown that total objectivity is not possible because people actually construct their understanding of the world through "constructionist neurological processes", by building on existing knowledge (Littledyke, p. 5). Lastly, it is now recognised that science is uncertain as it cannot offer guaranteed outcomes because it is impossible to accurately predict the outcomes of interactions that take place in complex systems, such as Earth's biosphere. Instead scientists interpret these systems and convey information in terms of probability, which is in turn expressed in terms of risk and uncertainty (Littledyke, 2008).

This post-normal view of science which acknowledges uncertainty and unknown consequences, especially when considering today's complex socioscientific issues that are high stakes like global warming, means that experts and scientists alone can no longer make decisions about solutions (Colucci-Gray et al., 2006). In addition, because these complex issues are contextual and values-dependent, many points of view about potential solutions are put forward with experts often having conflicting ideas. Since post-normal science takes context and the complex nature of socioscientific issues into account, it recognises that science alone cannot provide solutions. Instead there is a need for experts, scientists and the public to form partnerships so that the public can take part in the decision-making process because they are the stakeholders in any issue. People with this view of science argue that there is a greater need for the public to be scientifically literate to be able to take part in decision-making processes.

Even though a post-normal view of science is often found in science education literature, for example Hodson (2011), Levinson (2010) and Skamp (2009), in many countries school science appears to have retained its modernist view of science which can be seen in the way that much science education is still content driven and does not relate to students' everyday experiences (Levinson). Science knowledge is often taught in discrete 'chunks', with students required to learn concepts such as photosynthesis or anaerobic respiration (Gray & Bryce, 2006; Kim & Roth, 2008). Such concepts are usually presented in a decontextualised manner, which can make it difficult for students to relate science to their own experiences (Lester, Ma, Lee & Lambert, 2006). As a result, students do not learn about the uncertainty of science or to give consideration to whole systems (Colucci-Gray et al., 2006). In addition, there is the issue of assessment affecting learning programmes as one of the goals of secondary science education is enabling students to achieve the standards set to gain admission to tertiary education (Ashley, 2000; Gough, 2007). As a result of these pressures, learning in science at school mostly involves the cognitive domain and rarely involves the affective or social aspects of learning (Hodson, 2003).

In recent years some science educators have proposed different ways of teaching and learning in science in an attempt to present science to their students in a postmodern manner. One such approach is the STS (Science-Technology-Society) movement which has recently been expanded to become STSE to include the environment (Hodson, 2011). The central tenet of this particular type of science education was to include study of the many perspectives of science – its social, political, cultural, historical, philosophical, ethical and economic perspectives (Lester et al.). STSE promotes "habits of mind", such as skepticism, open-mindedness, familiarity with forms of inquiry, managing uncertainity and critical thinking and was based on a theoretical framework that drew on the sociology of science (Hodson, p. 30). It included two elements:

1. The way in which scientists interact with each other within the scientific community (*internal* interactions)
2. The way in which scientists and science interact with issues, institutions and society outside of the scientific community (*external* interactions).

Although STSE had this theoretical framework, it was not tightly prescribed in order to allow a wide range of approaches and interpretations (Solomon & Aikenhead, 1994). However, concerns about the STSE approach have been raised. For example, Kim and Roth (2008) assert that teachers have treated STSE as an add-on to their content-rich programmes, giving students little opportunity to discuss new scientific ideas and their impact on society. Zeidler, Sadler, Simmons and Howes (2005) go further, pointing out that while STSE affords learners the opportunity to examine the ways in which science and technology affect society, STSE neglects the moral and ethical dimensions needed when making decisions about science-based issues. They promote another form of science education that uses learning situated in the context of a socioscientific issue (SSI). An SSI is a scientifically-based social issue that is contentious and is connected to either scientific conceptual or procedural knowledge (Sadler, 2011). It is an issue that is open-ended with many possible solutions that can be partially but not totally informed by science. In this way, an SSI approach can involve values, ethics, politics and economics. Sadler argues that by situating science learning in the context of an SSI, students can explore an issue relevant to them, by learning to cope with the way in which science is represented in an issue relevant in today's society.

These approaches to science education appear to address some of the problems encountered when teaching with a modernist view of science within science education and are in line with the Organisation for Economic Co-operation and Development's [OECD] recommendation that students need to engage in authentic and real issues in order to foster a lifelong interest in science (OECD, 2007). However, Hodson (2003, 2011) argues that the STSE approach to science education falls short because it does not include students developing political literacy, namely knowledge and skills about political processes such as lobbying and making submissions so that they can participate in democratic processes in a critically informed way (Tilbury, 1995) and it would appear that SSI education also lacks this aspect. As discussed before, effective science education should enable students as future citizens to be: informed consumers of science; capable of critical thinking; able to make changes to achieve a more socially just society; and contributors to efforts to develop and maintain a sustainable environment. While STSE does assist in helping students to understand how scientific knowledge is constructed in a socio-political context and SSI-based education has a focus on the moral development of learners, because they do not develop students' abilities to take considered action for change, both fail to meet Hodson's vision of effective science education.

A further problem with science education is the lack of students' affective engagement (Hodson, 2003). This lack can be seen in the way that students feel disillusioned and alienated from science (OECD, 2007). In addition, students' attitudes towards science are becoming less positive as they progress through their education, leading to fewer people choosing to make science their career on a worldwide scale (Littledyke, 2008). This downward trend of interest in science is evident in the latest data available from New Zealand where 64% of Year 4 (8-9 years old) students said that they enjoyed doing science at school but by Year 8 (11-12 years old), the numbers of students enjoying science at school had dropped to 24% (Crooks, Smith & Flockton, 2008).

What is clear is that a different approach to science education needs to be implemented that presents a post-normal view of science, is relevant to students' lives and will enable them to be consumers of science who can take a personal position on issues, then make informed decisions and take action to effect change.

A Reconstruction of the Relationship between Science Education and Education for Sustainability

One way through this problem could be to integrate a form of post-normal science and EfS programmes for the mutual benefit of both areas of learning. Science and EfS do have an historical link since it was scientists such as Rachel Carson with her publication of *Silent Spring* and Paul Ehrlich's book *Population Bomb* that began to raise the public's awareness about environmental degradation in the 1960s (Tasar, 2009). EfS in its earlier form of environmental education came into education through the science curriculum (Gough, 2007). However, in the latter part of last century, concerns about the role of science in EfS emerged which culminated in UNESCO calling for a re-orientation of education towards sustainability that was formalised in *Agenda 21* (Tilbury, 1995). Environmental educators thought that science educators had a narrow and superficial view of what EfS entailed (Skamp, 2009). These concerns centred around a perception that science education had a modernist view of science and lacked an ability to engage students in both personal and community issues. This type of science education was also seen as not including the affective and social dimensions of learning, as well as being unable to acknowledge and clarify people's values and assumptions about the underlying power structures of society (Tsevreni, 2011). Environmental educators had recognised the political nature of EfS and realised that science education in its modernist form would not meet the needs of the type of education that was now being advocated (Gough, 2007).

As a result, a 're-orientation' of EfS was promoted, a type of education that was interdisciplinary, values-focused, participatory and aimed to politicise students (Tilbury, 1995) and shifted from a single focus on environmental (ecological) knowledge to include understandings about a far broader range of factors that contribute to environmental issues, such as societal, economic and political factors. In this way EfS and science education became estranged. However, EfS has its own particular set of problems. For example, in New Zealand EfS is marginalised due to teachers viewing it as yet another pressure in an already overcrowded curriculum (Eames, Cowie & Bolstad, 2008). In many countries EfS does not have the status of being a learning area in its own right and the cross-curricular or infusion approach that is usually adopted can also affect its teaching (Eames et al.; Skamp, 2009). Furthermore, there are funding issues. In 2008 with the change to a more right-wing government in New Zealand, funding for supporting teachers to implement EfS programmes was cut. Australia's EfS programme, the Australian Sustainable Schools Initiative (AuSSI) that provides support to over 30% of Australian schools has also had all of its federal funding cut (The Australian Education for Sustainability Alliance [AESA], 2012).[1]

Recently some environmental educators have called for a reconstruction of the relationship between EfS and science education (Gough, 2007; Skamp, 2009). One of the reasons is that the concept of sustainability is generally perceived as having three components: social, economic and environmental (Sterling, 2010). The environmental component of sustainability, where an understanding of how the many different ecosystems in our biosphere function is required, needs scientific knowledge which informs people's decisions about actions to be taken to resolve an issue. However, when considering an environmental issue, the social and economic components also need to be taken into account. For example, one study found that scientific knowledge can help move students' understandings about the effects of litter on the environment, from an aesthetic viewpoint to a scientific understanding, such as decomposition issues and biological oxygen demand. This scientific knowledge not only gave substance to students' feelings of concern for the effects of litter on the flora and fauna of a waterway, it also provided justification for their actions taken to resolve an issue (Birdsall, 2010).

This idea is reflected in the United Nations Decade of Education for Sustainable Development Implementation Scheme which states:

> The role of science and technology deserves highlighting as science provides people with ways to understand the world and their role in it. Education for Sustainable Development [another name for education for sustainability] needs to provide a scientific understanding of sustainability together with an understanding of values, principles and lifestyles that will lead to the transition to sustainable development.
>
> (UNESCO, 2004, p. 18)

Further weight for the argument of integrating science and EfS in schools is found in the results from 2006 Programme for International Student Achievement [PISA], an international survey of students. These results suggested that the better students' understandings of science, the more aware they were of environmental issues and the greater their feelings of responsibility for sustainable development (Uitto, Juuti, Lavonen, Byman & Meisalo, 2011). Sterling (2010) also agrees that knowledge is needed when dealing with the complex issues facing today's world.

Gough (2007) asserts that reconstructing this relationship could also address the decline of students' interest in science, especially amongst girls. She argues that since students' interest in environmental issues is increasing, EfS could be a vehicle for re-igniting interest in studying science because of their environmental concerns. In addition, given that EfS occupies a marginalised position in the school curriculum (Eames et al., 2008; Gough), its inclusion in science education could provide EfS with space in the curriculum, thus moving it out of its currently marginalised position.

Similarly to science education, EfS has its own particular pedagogical philosophy and approaches. At the core is the belief that EfS should be transformative in nature (Nolet, 2009; Sterling, 2010). Both Nolet and Sterling argue that our current education systems serve to perpetuate beliefs, values and behaviours that have resulted in our current environmental and social issues. Such reproduction occurs because schools continue to transfer contemporary culture and values (Hart, 2010). Therefore, in order for education systems to bring about change, education itself will need to change first. It is hoped that EfS could generate that change.

With the aim of effecting this type of change, EfS is conceptualised as learning that involves the head, heart and hands, a term first coined by Lucas (1979). These three types of learning can be summarised as:

- Heads learning that is located in the cognitive domain and involves the development of understanding about sustainability; content knowledge about environmental issues; critical thinking skills (Sipos, Battisti &Grimm, 2008); and a whole systems approach when considering an issue (Sterling, 2010).

- Heart learning that is located in the affective domain and involves the development of values and attitudes (Sipos et al.).

- Hands learning that is located in the psychomotor domain where learners are able to take informed, practical actions based on understandings, values and attitudes developed (Sipos et al.)

In addition, EfS involves learners being involved in real world problems, rather than hypothetical situations in the belief that such involvement will assist them learn the way in which their world works and their place in it (Sipos et al., 2008). By tackling real world problems learners have opportunities to relate to and further develop their understanding of environmental issues (Brundiers, Wiek, & Redman, 2010). Working to enact solutions to real world issues enables learners to gain practical experience linking understandings to taking actions as well as raising their awareness of their values position and those of others. Also, being engaged in a real world issue means that learners are faced with the 'messiness' of an actual issue and the need for negotiation and conflict resolution in order to come to agreement about solutions (Brundiers et al.).

Finally, EfS is seen as participatory, democratic learning (Sterling, 2010). Such an approach involves a less prescriptive type of education where learning is open-ended and students are encouraged to be autonomous. Because learning is done with others, skills of cooperation and negotiation are important (Stevenson, 2007a).

Reconstructing a relationship between science and EfS could result in a revised framework of learning that could be located under the 'umbrella term' of sustainability education (Nolet, 2009). Such a framework could then be used when investigating an environmental issue. Therefore, based on a post-normal view of science, incorporating EfS pedagogy mentioned above, along with Tilbury's (1995) EfS components, such a revised framework could include components such as a(n):

- Development of an understanding of sustainability
- Issues-based form of learning that is set in relevant contexts for students
- Understanding of the conceptual and theoretical scientific knowledge related to the issue
- Ability to access and critically evaluate information as required using technologies
- Appreciation of the nature of science and scientific inquiry so that the quality of evidence claims can be evaluated
- Ability to express and justify an informed personal viewpoint
- Appreciation that people's differing viewpoints that promotes diversity
- Clarification and examination of personal and social values
- Ability to envisage possible and probable futures
- Ability to reach conclusions and make decisions that can be justified through critical reflection
- Political literacy to empower students to take part in democratic processes such as lobbying or making submissions to local governments
- Ability to take action to mitigate or resolve issues and reflect on its efficacy

(Adapted from Hodson, 2011; Sipos et al., 2008; Sterling, 2010; Tilbury, 1995).

However, as Hodson (2011) notes, enacting a curriculum that includes these components is an "extraordinarily tall order for teachers" (p. 297) that requires change at all education levels from the classroom to teacher education institutions to educational policy. The inclusion of these aspects not only fundamentally changes the curriculum and challenges the traditional functions of schooling, such as the reproduction of society and the production of a workforce for the global economy (Stevenson, 2007b) but their inclusion could lead to widespread social change (Hodson). Nevertheless, Hodson argues that a drastic change to a sustainable way of life is imperative for the survival of future generations of people. Sterling (2004) concurs and views this change as risky because no one actually knows what a sustainable society would look like, thus making it extremely difficult for educators to know how to achieve the goal of preparing students for an unknown future.

The purpose of this paper was to explore whether components of science and EfS could be combined in a way that could reflect a revised approach to science education and EfS. It was anticipated that the outcomes could be that students gained a deeper understanding of scientific concepts and were able to take action on an environmental issue. In addition, this paper sought to provide a compilation of an account of teaching science in the manner suggested by Hodson (2011). He argues that we need such compilations so that other educators can learn about the successes and failures of teaching in this way, as well as identifying barriers and their possible solutions. The following sections in this paper illustrate the way in which some components from this broader framework of learning were implemented during an investigation of an environmental issue by a group of students and the effects on their learning.

Research Design

These illustrations of the framework's implementation were framed using an interpretive research design that used a qualitative methodology. This type of design was chosen because it allowed a naturalistic approach that aimed to understand students' ideas and opinions (Sarantakos, 2005). This approach also allowed the researcher to interpret these students' experiences and understandings based on the view that people construct their view of reality through their interactions with others as they make sense of their world (Merriam, 1998).

Context and Participants

This research was carried out in a high decile ranking New Zealand school[2] in which EfS programmes were not taught at all. Although the entire class of 28 students who were aged between 11-12 years participated in the learning programme, a complete data set was gathered from 22 students. These students had given their consent to participate and had also gained parental consent. Additionally, permission for the research to take place was sought from the school's principal and the students' teacher. These consent forms were pre-approved by a university-based Human Participants Ethics Committee.

There were approximately equal numbers of girls and boys in the sample. This group of students exhibited abilities that were above average for their age. For example, approximately 74% had a reading age above their chronological age and just 9% were reading below their chronological age according to school records.

The Programme

The researcher and the classroom teacher planned the programme collaboratively based on the requirements of New Zealand's national curricula documents (See Appendix 1 for details). The programme covered many learning areas, such as technology, social science and visual arts, as well as including two characteristics of science education, scientific concepts and process skills. Examples of the concepts taught were the water cycle, eutrophication, weathering and erosion, food chains and indicators of a healthy waterway. The process skills developed included observation, data collection, collation and interpretation.

The programme was set in the context was the local freshwater lake that these students visited as part of their school's outdoor education course that involved swimming, kayaking and sailing. This context was chosen because there had been conflicting reports about the lake's water quality in local newspapers. When brought to their attention, these reports sparked the students' interest and they wanted to find out if the water quality was good enough for them to be able to continue using the lake.

The programme ran for 15 weeks of the school year within the class's usual timetable. It was mostly taught by the students' teacher with the researcher teaching the science and drama as well as facilitating discussions. The programme did change the way in which the learning areas of science, social science, health, technology and drama would have been taught. However, writing, reading and art were taught in the same way. A separate maths programme ran concurrently along with an additional reading programme.

Because the purpose of the programme was to integrate both science and EfS, the programme was underpinned by the concept of sustainability. Since sustainability is a contested and complex concept (Corney & Reid, 2007), it was contextualised in terms of the lake's ecosystem and the complexity of the information provided took into account these students' young age. Consequently, throughout the programme sustainability was referred to and discussed as comprising of two components:

- *Environmental* making careful decisions about the environment that keep or improve its quality together with ecological understandings about the lake in terms of the characteristics of biodiversity, interdependence and cycles

- *Social* the decisions made about the environment in the past affect the present and the future, and the decisions made about the environment in the present will affect the future of the students' children. The idea that decisions made in the present should not reduce the choices of people in the future was also included.

The economic component was not included in the contextualisation because the students' teacher wanted a focus on scientific concepts and processes during the programme. In addition, since the lake is a community resource and available for all residents to use free of charge, the teacher thought that the environmental and social components were of greater importance and enough of a challenge for students to comprehend.

Data Collection

Data were collected using the following instruments: semi-structured interviews with individual students; interactions with a values continuum; an annotated drawing showing a future use of the lake and justification in terms of its sustainability; and a written task involving choosing a scenario related to a way of using the lake with similar sustainably-based justifications. These written tasks provided an opportunity for students to indicate their understanding of scientific concepts as they justified their decisions for possible sustainable solutions. A further opportunity arose to collect data when a notice was found in the local newspaper, notifying the community about the local council's proposed changes to the management of the parks and reserves that partially surround the lake. Students took up this chance and made a submission based on their findings about the lake's water quality and their ideas about its management.

Data were collected at five different points during the sustainability education programme. Pre- and post-teaching semi-structured interviews were carried out with individual students where each student was asked to explain their understanding of sustainability. Students' ideas were then discussed with the researcher to clarify and probe their ideas.

A values continuum was also completed both pre- and post-teaching. The continuum was developed by the teacher and researcher for this project. It had seven statements relating to waterways with a five point scale under each statement ranging from 'Strongly Agree' to 'Strongly Disagree' and the students had to choose one point (See Appendix 2). When completing the continuum at the conclusion of the programme, students were asked to explain any changes they had made to their continuum at the end of the teaching programme.

The first written task was completed six weeks into the programme. It was developed by the teacher and researcher as means of both collecting data and assessing the students' progress for school records. It involved the students identifying a possible future use of the lake and then justifying their choice in terms of their understanding of sustainability.

The second written task was completed 13 weeks into the programme. Similarly to the first written task, it was developed for both data collection and assessment purposes. It involved a structured role-play activity known as a goldfish bowl technique (Cheek, 2010). The class was divided into seven groups and each group was provided with a different scenario. Each scenario described the way that a particular group of people in the community wanted to use the lake. For example, one scenario was the Forest and Bird Society who wanted to create a sanctuary for native wildlife, eliminate all exotic plant and animal species, close off access to certain areas for native forest regeneration and control pests like dogs and cats living around the lake. In contrast, another scenario featured a land developer who wanted space to erect 20 residential units for elderly next to the lake, create a park-like atmosphere surrounding the development and construct a concrete carpark for residents and visitors. After each group had presented their scenario to the class in a role-play, the class discussed the merits of each scenario. Following this class discussion, each student had to choose a scenario that they felt was the most sustainable and then justify their choice in terms of their understanding of sustainability. Finally, there was the submission to the local council mentioned above.

Data were analysed thematically (Braun & Clark, 2006) in terms of the revised framework components, the scientific concepts used and the way in which scientific ideas were used to justify their ideas or actions. In addition, students' responses were analysed in terms of the two components of sustainability taught. This analysis resulted in three categories of responses, namely environmental, social and a combination of both.

Validity and reliability are an important part of carrying out research. However, as an interpretive project, the criteria for assessing these are different (Lincoln & Guba, 1985). Three strategies were used to enhance this project's validity and reliability, or what is termed credibility and dependability in interpretive projects (Merriam, 1998). Firstly between-method triangulation was used as different types of data gathered using different instruments were used to measure the same phenomena. This use of multiple methods of data collection also enhanced the dependability of the findings as cross-checking of analysis and students' responses could take place. Secondly, the students' transcripts were returned to them for verification following transcription. Finally, a pilot study using the interview protocol was conducted, enabling refinement of the process to take place prior to the main study (Neuman, 2003).

As a small-scale study in a particular context, it is difficult to make generalisations. However, interpretive studies rely on a reconceptualisation of generalisability where the extent to which a study's findings apply to other situations is left up to the reader (Merriam, 1998). In order for the reader to be able to do this, a "rich, thick description" of the students' ideas and actions has been provided so that a reader will have sufficient detail to be able to make such a generalisation (Merriam, p. 211).

Results

It has been suggested that a reconstruction of the relationship between science and EfS could result in a revised learning framework that contains 12 components. Data were analysed using these components and illustrations of each component will now be presented in turn.

Development of an understanding of sustainability

The first component in the revised framework is developing an understanding of sustainability. Students' understandings were analysed over the duration of the programme. The findings show that at the beginning of the programme three students had an understanding of sustainability and by its conclusion, 21 had developed some understanding (see Appendix 3). While Appendix 3 illustrates that all but one of these students were able to express an understanding of sustainability at the conclusion of the programme, it also shows that 19 expressed their understanding in terms of either environmental or social ideas. Only two students were able to express a combination of both, which is suggestive of a more complex understanding. This finding illustrated the difficulty of developing a complex understanding of sustainability that involved more than one component.

Student responses that were placed in the *No Related Ideas* category did not relate to an environmental or social idea of sustainability and examples from the initial interviews were:

> ... *it means clean and tidy* ... (S12)
> ... *it's something that is really good or beautiful* ... (S8)

Responses that were placed in the *Environmental Understanding* category related to caring for the lake and often included scientific concepts. An example of such a response included:

> *The lake wouldn't be sustainable if it was filled with rubbish, then the water would get polluted and the animals in the water wouldn't have clean water ... so the fish can breathe, otherwise they get clogged up gills ... so the plants can't get light through the water so they can't make their own food ...* (S18)

In this response during her final interview, S18 showed her understanding of sustainability through the effects of rubbish decomposing in the lakewater, affecting its oxygen level and subsequent effects on fauna. She also believed that fragmentation of rubbish would adversely affect the lake's sustainability by blocking light, which would impact on plants' ability to photosynthesise.

Ideas that were placed in *Social Understanding* category related to concepts such as intergenerational equity, past decisions affecting the present and decisions made today affecting the future. An example is S14's response in her final interview and she said:

> *I think that the word sustainability means something to be healthy and safe like when we went down to the lake we made sure everything was healthy ... because it's in our area and we're trying to keep it ... for the people of the future so they can go down and because it's one of the most historical things that we have ...* (S14)

S14's response illustrated her belief that the lake needed to be kept in the same condition as she found it so that future generations could visit the lake just like she had. It also showed her feeling of responsibility for the lake because the lake was part of her community.

S11 was one of two students who were able to combine environmental and social ideas to in his expression of sustainability in the final interview and he thought sustainability meant:

> *... keep something good and something healthy that ... will last a long time so that people after you will benefit from it as well ... like the lake really. Like we tested the water quality and we found out that it was good and now we're going to try and improve it so that the people after us will benefit from it and so it won't just dry up and it won't be there anymore. But it will be because we're helping to keep it clean and healthy ... if we plant trees, they won't grow straight away but after a while they will grow and they will help make shade around the lake ... cools the water and it means more dissolved oxygen ... it's easier for the macroinvertebrates.* (S11)

The example that S11 gave about trying to improve the lake's water quality for the benefit of people in the future showed that he was able to apply his understanding of sustainability as both caring for the environment and intergenerational equity to a real life example. It also showed that he was aware of the need for people to take informed action for the environment to ensure it is cared for and preserved for future generations. Furthermore, his response demonstrated his understanding of the relationship between water temperature and the oxygen level of water and the way in which macroinvertebrates are dependent upon oxygen for survival.

Issues based form of learning set in a relevant context

The next component is situating the learning around an issue that is relevant to the students that provides a relevant context for learning. In this study, the issue of the local freshwater lake's health had been raised in local newspapers and provided conflicting reports about its water quality. These reports provided the impetus for beginning the study because students were familiar with the freshwater lake and used it for a water-based outdoor education programme on a regular basis during summer. Their familiarity with the lake had an influence on their developing ideas about the concept of sustainability. For example in her final interview, S19 gave this response as an illustration of sustainability that was categorised as a social understanding:

> *… if we make a little school for teaching children how to kayak and sail that might be a pretty sustainable thing because like it won't harm the lake and in the future children can actually learn how to use the lake more …* (S19)

Here S19 took her experiences at the lake and thought children in the future also could take part in these activities, just like she had. In addition, she thought that kayaking and sailing would be sustainable because they would have no impact on the lake's water quality.

Understanding of the conceptual and theoretical scientific knowledge related to the issue

Students' responses showed that during the programme, they developed relevant conceptual and theoretical scientific knowledge, which was the second of the revised framework's components. Not only did the number of students using scientific concepts in their explanations increase, the students' understandings of the scientific concepts became more complex as they were able to use scientific concepts in their explanations or justifications. For example in the first written task three students were able to justify their ideas about possible future uses of the lake in terms of their understanding about the effects of rubbish in and around the lake. S13's response showed an emergent awareness of the effects of decomposition and biological oxygen demand on water quality and consequently, fauna would be harmed that was placed in the *Environmental Ideas* category:

> *There will be a robot … will pick up all the rubbish around the lake … and protect the wildlife … you'll also face charges when [the robot] sees you throwing rubbish and harming our precious wildlife.* (S13).

While no students demonstrated an understanding of this concept in the second written task, six students used their scientific knowledge of how decomposing water could reduce the oxygen level to justify their understanding of sustainability in the final interview. S1's response, categorised as *Environmental Ideas*, illustrated that he not only had an understanding of the effects on fauna, he also had an understanding of effects on plants in that plants also need oxygen:

> *… when you put the litter in the lake, sometimes it might not go away and it will just stay there and then the animals inside there [the lake] will find it hard to breathe … or they might get trapped inside the litter it'll dirty the lake and all the animals and plants can't breathe and they can't find their food because it's way too cloudy inside there and it's hard to move around.* (S1)

These students also developed understanding of the effects of erosion on the lakewater and that sedimentation will affect the amount of light and consequently photosynthesis. Four students used this concept to justify their ideas that were categorised as *Environmental Ideas* in their final interviews. For example, S18 referred to the rocks that had been placed at the edges of some parts of the lake's bank and said:

> *… there's now stone around it so the lake doesn't get bigger and shallower … the fish can breathe otherwise they get clogged up gills … so the plants can get light through the water so they can make their own food …* (S18).

In this response S18 showed an understanding of the process of erosion and the transportation of sediment to the bottom of a lake. It also revealed that S18 also had an understanding of the effects of sediment on the lakewater flora's ability to photosynthesise and fauna's gaseous exchange processes.

In their final interviews, some students were able to use more than one scientific concept to justify their ideas. For example, S16 talked about the trees being planted around the lake contributing to the sustainability of the lake:

> *… the trees are there because the roots grab the soil and … the soil won't go down to the lake because the soil … might have fertiliser in it and fertiliser's bad for the lake because of nitrates. Too much nitrates can upset the balance of the lake … the soil would probably cloud the water and they [macroinvertebrates] won't be able to breathe and if it [soil] crawls onto the plants, then the plants won't be able to breathe and make food.* (S16).

In this *Environmental Ideas* categorised response S16 demonstrated her understanding of three scientific concepts the role of tree roots in preventing erosion, the effects of unstable soil leaching nitrates and the effects of sedimentation on the lake's flora and fauna. Not only did her response illustrate her understanding of sediment affecting the ability of the lake's plants to photosynthesise and the lake's animals' gaseous exchange processes, she also demonstrated understanding of the effects of nitrates. The level of nitrates in a waterway is an indicator of its health. If the nitrate levels are too high, it can alter the ion exchange in the water which in turn has detrimental effects on a waterway's flora and fauna. Four of the students used this concept to justify their ideas in the final interviews.

Accessing and evaluating information using technologies

The third component is being able to access and evaluate knowledge as required by using technologies. When studying the lake's ecosystem and in particular, the types of macroinvertebrates that could be found in the lake, these students gathered data by sampling macroinvertebrates, using a clarity tube, thermometers, as well as nitrate and pH strips when carrying out water quality testing at the lake. They then made sense of these data based on information found in books, on websites and from a video. Based on data and information found, these students were able to explain and justify their ideas. For example, when asked to discuss her ideas about the meaning of sustainability in the final interview, S22 explained sustainability as:

> *… it's [the lake] not polluted and there's no rubbish or anything … then it would be sustainable … because it [rubbish] would make it like really unhealthy and then not the highly sensitive creatures like the stonefly nymph would live in the lake, only the very unsensitive to pollution bugs would live in it.* (S22)

In this response categorised as Environmental Ideas, S22 was referring to information accessed that explained the way that particular macroinvertebrates were bio-indicators of a healthy waterway whereas other species were pollution tolerant. She was able to use her knowledge about decomposing water and its effects on oxygen levels and then link it to her knowledge about stonefly nymphs as bio-indicators of high water quality to justify her definition of sustainability in the context of the lake.

Appreciation of the nature of science and scientific inquiry

The next component of the framework is gaining an appreciation of the nature of science and scientific inquiry so that the quality of evidence claims can be evaluated, forming a basis for informed decision-making about possible solutions. These students gained an appreciation of scientific inquiry as they made observations about the lake's catchment area and appearance of the water. They tested the quality of the water by measuring its temperature, pH level, level of nitrates present, turbidity and sampled the macroinvertebrate population. Data were recorded and trends in the macroinvertebrate sampling identified. As a result, students were able to draw conclusions about the lake's water quality. Their ability to use data in this way was illustrated in a report written and published on the National Waterways Project website:

> *We caught 42 macroinvertebrates altogether and we recorded what group they were in according to their sensitivity to pollution. We found out the turbidity is 95% crystal clear and the temperature is 12 degrees which means that the lake is very healthy. We also found out the pH is 6.5, which is excellent and there are low levels of nitrates … which also indicates very good water quality.* (NWP Report pp. 2-3).

Students also gained an appreciation of scientific inquiry as they found out that the water quality results differed slightly between groups. This finding provoked discussion about how scientists cope with variation in data and one student made mention of this in his final evaluation:

> *If I were to change the study, I would do down to the lake a few more times and test the water in a few different places instead of just one.* (S1).

Express and justify an informed personal viewpoint

Another component in the framework is developing the ability to express and justify an informed personal viewpoint that can also inform decision-making and taking of action. During the course of the programme, these students developed personal viewpoints about how the lake should be cared for and were able to justify their viewpoints using knowledge that they had developed. Some used scientific knowledge such as S6 who in the second written task wrote:

> *I think the Forest and Bird Society is the best for the sustainability of the lake … because we can use the lake as a sanctuary to save native birds and plants from being extinct … we'll control pests like cats and dogs near the lake. The reason I do this is because cats will eat the birds and eggs. The dogs will scare the birds away and they will never come back.* (S6).

In his response, S6 demonstrated his understanding of conservation to prevent extinction (*Environmental Ideas*). He also discussed predator-prey relationships when identifying the need to control cats and dogs so they did not harm the birds.

Other students adopted a viewpoint of being guardians for the future categorised as *Social Ideas*, justifying their opinions because of the lake's beauty and intergenerational equity. S10's response in the second written task illustrated this stance:

> *I chose this scenario [Keep the Lake Beautiful] because it's a beautiful lake and I want it to stay that way so future generations also have a beautiful lake. It will also attract people to come to the lake and enjoy the surroundings. It is a great place for people to walk around and to have picnics without being disturbed … I also chose it so future generations can experience what I have experienced at the lake.* (S10).

Appreciation of differing viewpoints to promote diversity

A further component of the revised framework acknowledges the way that when working towards a solution to a problem, there is a range of differing viewpoints that need to be respected by all. During this programme students did have differing viewpoints, especially when it came to writing the submission where there were two groups with strongly held views. After discussion, it was decided to include both viewpoints and the following extract from their submission to the local council about the management of the reserves surrounding the lake illustrated these opposing viewpoints about the management of rubbish:

> *We think that the current level of litter in and around the lake is unacceptable, dangerous for wildlife and could be affecting the water quality of the lake … had two different ideas about the number of rubbish bins. One group of people in our class thought that more rubbish bins would help reduce the amount of litter. Another group suggested that all rubbish bins be removed and users and visitors to the reserves have to take all of their rubbish out with them.* (Submission pp. 2-3)

Their submission also illustrated the use of students' scientific understanding about the decomposition of rubbish and biological oxygen demand to justify their recommendation to the council.

One student revealed her appreciation of differing viewpoints about pet ownership when residing next to a wildlife sanctuary when justifying her choice of scenario in the second written task:

> *The idea of controlling pests like cats and dogs from going near the lake is a good idea because cats love to catch birds and dogs might chase the birds away but the problem is that people that live close to the lake would have to move to another place to live or give away their pets.* (S19).

S19's reasoning also illustrates her growing understanding of scientific concepts such as conservation and the need to foster a wide diversity of flora and fauna. Her response also reveals her understanding of issues that arise when people interact with their environment. In this instance it is the issue of pet ownership next to a sanctuary and S19 was able to identify two potential solutions.

Clarification and examination of personal and social values

The next component in the framework is clarifying and examining personal and social values. These students completed a values continuum at the start of the programme and again at the end. They were asked to give reasons if they had changed their position since the beginning of the programme. Their learning did appear to help these students clarify their personal values. For example at the beginning S9 marked the 'Strongly Agree' point for the statement 'It is better to use an unspoiled river for recreation, rather than keep it as a natural habitat' but he changed his position to 'Strongly Disagree' at the end giving this reason:

> *I strongly disagree from changing the lake to an unspoiled river for recreation because I want the birds to be safe.* (S9).

This change in response illustrated a change in the value that S9 placed on birdlife. Prior to the programme he thought that a river should be used for recreation. However, after having learnt about the lake's fauna, he changed this belief and now valued the lake as a 'natural' place.

The continuum exercise also allowed students to explore social values because one of the statements related to the idea that New Zealanders care for their environment. At the end of the programme this statement was changed by 13 of the students, the most significant amount of changes made. Except for one student, 12 out of the 22 students made a change towards the 'Strongly Disagree' end of the continuum. Reasons given were similar and related to the amount of rubbish that the students had observed in and around the lake and their realisation that people were responsible for leaving this rubbish. S20's justification is representative of these students' responses:

> *I changed my opinion on the statement 'New Zealanders care for the environment'. At first I strongly agreed about it but now I'm not so sure [changed to neutral] having discovered all of the rubbish around the lake.* (S20).

This response illustrated the way that initially students thought that everybody looked after the environment in New Zealand but their observations showed them that their perception was not applicable to all New Zealanders as evidenced by the rubbish at the lake.

Envisaging possible and probable futures

Having the ability to envisage possible and probable futures is the next component in the framework. Students developed this ability as is shown in S23's justification for her choice of scenario in the second written task:

> *The Forest and Bird Society has the best ideas for helping New Zealand native animals and plants. The ideas would help the native animals by keeping them from extinction and would help the native plants by giving them an area to grow and regenerate. The lake would be a completely native area for people to enjoy … now and also people in the future would still be able to enjoy the lake in the same way … where it is safe for native animals and plants … and where there isn't any pests.* (S23)

Her response which was categorised as a combination one, demonstrated the way in which she used her scientific knowledge to envisage a future for the lake. She used concepts such as maintaining biodiversity of native flora and fauna and predator-prey relationships to justify her vision.

S21's explanation of sustainability in the final interview also demonstrated ability to envisage a future for the lake and people:

> *It's good for the environment because could be more options ... for people of the future ... like for the lake to keep it sustainable you could have a group who wanted to*

> *build native bush walks and that would be good for people and it would be sustainable because it would help the environment grow back ... from when people cut down all of the trees ... [when asked why, replied] because then people might understand about how New Zealand was before people came and chopped down trees and they might want to help.* (S21)

In this response S21 articulated her vision of the future as being the construction of native bush walks around the lake. Not only did she view this as a restoration project from which both the environment and future generations would benefit, S21 also envisioned that it would encourage other people to care for the environment. This response was categorised as a combination one.

Reaching conclusions and making justified decisions

Being able to reach conclusions and make decisions that can be justified is another component. This component was evident in the students' submission to the local council about managing the lake's reserves. As a group, they decided that there were too many mallard ducks, geese and black swans at the lake and instead they wanted more native birdlife. Their submission stated:

> *We think that the exotic birdlife should be controlled so that we can encourage our indigenous species … so provision has to be made to provide them with a suitable environment … we think that dogs should continue to be restricted from lakeside reserves and predators controlled through education and trapping programmes … should be extended to cats as they … have a significant effect on our indigenous birdlife.* (Submission, pp. 1-2)

Again, their understanding of scientific concepts was used to justify their decisions. They realised that populations of the exotic birds needed to be controlled in order for native species to have space to survive. In addition, they used their knowledge about predator-prey relationships to justify their decision to exclude both dogs and cats from reserves and agreed with the council's proposal to run education programmes about the need to exclude pets and also to trap those pets intruding on reserves.

Developing political literacy for empowerment

The penultimate component in the revised framework is the development of political literacy. Prior to this programme, these students had no knowledge about the role of the local council in maintaining reserves and waterways or the way that ratepayers could participate in making decisions about waterways. When the advertisement for submissions was published, it provided an ideal opportunity to discuss how ratepayers could lobby or make submissions about issues that they considered important. These students took this opportunity along with informing their parents, peers and community of their findings and consequently their political literacy skills could be regarded as emergent.

Taking action to resolve or mitigate issues

The final component in the revised framework is the ability to take action. The actions planned and/or taken included a litter clean-up, oral presentations to their peers and the school's Board of Trustees, a report to the National Waterways Project co-ordinator that was placed on their website, reports that were published in two local newspapers and a report for the local council's Environmental Officer as well as a submission to the local council about the management of the reserves and parks that surround some of the lake.

Discussion

These results suggested that reconstructing a relationship between science and EfS into a revised learning framework had been beneficial for students' learning in a number of ways. Firstly, these students were able to develop an understanding of sustainability. However, the majority could only express an understanding in terms of one component, either the environmental or social. This finding suggests that developing an understanding of sustainability in terms of its three components is very difficult for children of this age. It also indicates that the teacher's decision to not include the economic component was justified. Such a finding suggests that children's understanding of sustainability needs to be developed over time, with careful consideration given to aligning sustainability components to particular issues, for example in this instance, the environmental and social components seemed to be the best 'fit'.

As previously discussed, the goal of science education is to develop students' scientific literacy so that they can engage in debate and take an informed personal position on scientific issues. Development of their scientific literacy can be seen in the students' submission to the local council where they were able to take an informed position on two issues that is the need to create a wildlife sanctuary and forming an opinion about the effects of the amount of rubbish on this area. These decisions were based on their scientific understandings and these students went further, using their scientific understandings to suggest possible solutions.

In addition their actions demonstrated their emerging politicisation, in other words their knowledge about advocacy, in that they publicised their findings to their community through presentations and reports as well as writing a submission to the local council. According to Hodson (2011) and Tilbury (1995), the possession of political literacy is crucial in both science and EfS because it enables students to work individually and with others to bring about change towards a more equitable and sustainable world.

Hodson (2011) recommended that science learning take place in contexts relevant to students and Brundiers et al. (2010) also recommend studying real life contexts. Situating learning in their local lake where the students swim, sail and kayak did have an effect on their learning in that they became concerned about the amount of rubbish and exotic bird species in and around the lake. Their developing scientific conceptual knowledge enabled them to understand the effects of the rubbish and exotic birdlife on the lake and its environs and consequently, they developed an appreciation of the lake as a whole system that included the people who lived around the lake as well as those who made use of it. This appreciation then enabled these 11-12 year old students to envisage potential futures for the lake. Their visions empowered them to make decisions about actions they could take to mitigate or solve the issues they perceived as important to the lake's continued health.

While this finding corroborated Uitto et al.'s (2011) assertion that possessing greater scientific understanding results in more feelings of responsibility, this study went further and illustrated how students can then take action based on their feelings. Such a finding suggested that these young students found their learning personally relevant and engaging and substantiates Gough's (2007) suggestion that reconstructing this relationship could result in greater interest in science. These students' interest in science was apparent not only in their actions taken but also in the way that when asked to evaluate their learning, 17 of the 22 students stated that going to the lake to test the water quality and sample the macroinvertebrates was the activity they liked the most.

Furthermore, they were able to develop inquiry skills such as observation, sampling, recording, identifying trends in data and drawing conclusions. Students also developed a deeper appreciation of the way in which scientists work when confronted with groups having different results from their water quality testing. However, there was no follow-up to explore whether this interest was transferred into the next science topic taught and this highlights a space for future research.

Critique of the framework

The use of revised framework to design a programme of learning based on the environmental issue of the local lake resulted in these students developing some understanding of sustainability. Its use also enabled students to develop understandings about the lake, its environs and people as a whole system. The findings show that these students were then able to make informed decisions about actions to take based on their understandings. This finding implies that the development of knowledge is an important part of being able to take informed action. It runs counter to Kollmus and Agyeman’s (2002) assertion that there is only a weak link between knowledge and action, indicating a gap for further exploration of this relationship.

However, the framework would benefit from the addition of further components. For example, Hodson (2011) suggests that students develop media literacy so that they can critically engage with all types of texts and images to evaluate the strengths and limitations of information. Such a component would also relate to the idea put forward by Norris and Phillips (2003) that people need a wide conception of literacy in order to be able to interpret texts. While the students in this study did engage with some texts, there was the opportunity to think more critically about the two media articles that initiated the learning to explore why they presented two different viewpoints.

Another addition to the framework that was not included in the current study was developing knowledge about society’s underlying political, economic and social structures that affect the adoption of sustainability-driven imperatives (Hodson, 2011; Tilbury, 1995). Developing knowledge about such structures could have enabled these students to develop a deeper understanding about the amount of rubbish at the lake, beyond just people leaving it there. In addition, they might have developed a deeper understanding of why the lake was home to so many exotic birds and how the native flora and fauna were displaced by colonising settlers.

Furthermore, during the many discussions that took place during the programme, there was often disagreement between the students and they could have benefited from a final component, that of conflict resolution skills (Hodson, 2011). Such skills could have assisted them to resolve their disputes in a constructive manner.

Brundiers et al. (2010) argue that the use of real life contexts enable learners to interact with people in their community who also have an interest in the issue being studied. Additionally, such involvement offers another opportunity for developing an appreciation of diverse views and the development of negotiation and conflict resolution skills. While the role-play activity leading to the second written task did give these students the opportunity to examine different viewpoints, these were hypothetical. Engagement with stakeholders in the community would have brought more authenticity to these students’ learning and needs to be incorporated in future use of this framework.

Finally, Hodson (2012) claimed that this type of learning was very difficult to implement in classrooms. This paper has illustrated some of the difficulties. For example, there was the huge proportion of time such learning needs that might not always be available. New Zealand primary schools have four terms of approximately 10 weeks each and this programme took up 15 weeks. In addition, it had to be organised around other school events such as assemblies, sports days and a whole school drama production. There was also the issue of assessment. The teacher required data about student achievement for reporting to parents and school records and some of the learning was hard to quantify, for example the students' emerging political literacy and values positions. Finally, there were no other EfS programmes taught in this school during that year. These students had only begun to develop their understandings of sustainability and ability to engage in environmental issue decision-making and needed further learning to build on what they had learnt. Unfortunately there were no opportunities to do so.

In summary, a reconstruction of the relationship between science and EfS to form a revised framework has many benefits for learners. These 11-12 year old students developed their scientific literacy through the growth of their scientific knowledge and skills and the emerging ability to take action on issues of concern to them. EfS was able to be incorporated within the programme and these students demonstrated an increased interest in science. It would be fruitful to research the effectiveness of similar programmes, exploring their effects on students' learning as well as the impact on their lives outside of the school setting.

Endnotes

[1] Very recently EfS programmes in both New Zealand and Australia have received a modest amount of governmental funding. See http://tvnz.co.nz/politics-news/enviroschools-optimistic-after-budget-windfall-4900171 (New Zealand) and http://www.nationaltimes.com.au/opinion/society-and-culture/sustainable-australia-can-start-in-schools-20120621-20q23.html (Australia).

[2] The school has a Ministry of Education decile ranking of 10, meaning that this school is at the top level in terms of socio-economic rating and its predicted potential to access community resources and support.

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Appendix 1 – Outline of Programme

Learning Area	Knowledge and Skills Developed
Social Science	Researching history of lake, including interview with long-term resident. Studying consequences of past decisions on present day use of the lake. Values identification and clarification.
Science	Studying lake as an ecosystem. Effects of pollution and erosion on ecosystem. Water quality testing. Skills of observation, data collection and recording, interpretation of tables and graphs, drawing conclusions.
Technology	Design, construction and evaluation of nets to sample macroinvertebrates.
Physical Education and Health	Identifying actions that people could take to maintain the lake's water quality. Planning and implementing actions.
Mathematics	Using Excel to record data and draw graphs.
English	Oral language – discussions to promote critical thinking (groups and whole class) about lake in terms of sustainability. Reading – selecting, gathering, evaluating and processing information. Writing – writing explanations, letters and reports. Visual – designing a slide show of results for peers, parents and other teachers including the school's Board of Trustees.
Drama	Structured role-play activity about different uses of lake.
Art	Construction and printing of cardboard blocks depicting an historic building on lake's shore.

Appendix 2 - Values Continuum Activity

Read the statements below. Beside each statement is a scale. Place a cross on the scale above the word showing what you think about the statement.

Local waterways need to be protected.

Strongly Agree Agree Neutral Disagree Strongly Disagree

A variety of wildlife should be encouraged.

Strongly Agree Agree Neutral Disagree Strongly Disagree

People should be involved in local environment care.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Only ratepayers should contribute to the cost of caring for the waterways.

Strongly Agree Agree Neutral Disagree Strongly Disagree

New Zealanders care for the environment.

Strongly Agree Agree Neutral Disagree Strongly Disagree

It is better to use an unspoiled river for recreation, rather than keep it as a natural habitat.

Strongly Agree Agree Neutral Disagree Strongly Disagree

People should be made to spend some of their free time working towards helping the environment.

Strongly Agree Agree Neutral Disagree Strongly Disagree

Appendix 3 – Development of Students' Understandings of Sustainability

	Initial Interviews	First Written Task	Second Written Task	Final Interviews
No related understanding expressed	19	7	2	1
Environmental understanding expressed	3	13	6	3
Social understanding expressed	0	2	13	16
Combination of environmental and social understanding expressed	0	0	1	2