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Cultivating Attitudes and Trellising Learning: A Permaculture Approach to Science and Sustainability Education

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Abstract This article reports on an inquiry that used permaculture design thinking to create a science and sustainability education intervention for a secondary science class. The aims were to *cultivate student attitudes* towards science, towards learning science in school, and towards the environment, and to *trellis learning* of science and sustainability. Research into impacts of the intervention took the form of an interpretive, mixed methods case study, which included the use of questionnaires, interviews and observations. As a context for learning, local permaculture food production projects, as experienced through field trips in the intervention, appear to promote the *relevance* of science and sustainability learning and the ability to *engage* students. Science and sustainability learning outcomes appeared to vary among students, although nearly all of them reported they enjoyed learning science with a focus on the environment, including one group of students who reported they did not generally enjoy learning science in school. There was some evidence that the teacher transformed his own thinking through his participation in the intervention.

In this article we examine how food and science and sustainability education connect. Just as food nourishes living beings, the context of growing food has the potential to nourish science and sustainability learning — each of which suffers from malnutrition in many secondary schools around the world. Science learning appears to suffer from student disengagement (see Bolstad & Hipkins, 2008; Tytler, Osborne, Williams, Tytler, & Cripps-Clark, 2008), while sustainability learning (at the secondary level) appears to suffer from teacher disengagement (see Kim & Fortner, 2006; McDonald & Dominguez, 2010). Students complain of science teaching methods dominated by memorisation, lists, facts and figures (Keysar & Pasquale, 2008), some of the characteristics of science education criticised over many years by commentators such as Fensham (1985) and Gough (2004). As reasons for not engaging in sustainability learning, teachers cite an overcrowded curriculum, low confidence in taking children out of the classroom, a lack of resources and preparation time, and a lack of personal commitment to

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sustainability (see Bolstad, Eames, & Robertson, 2008; Kim & Fortner, 2006; McDonald & Dominguez, 2010).

Cultivating an environment that engages students and teachers in science and sustainability learning is not so different to developing and managing a healthy, productive, organic garden. By adopting an ecological design perspective such as permaculture, we look for deficiencies in the 'soil' that supports learning, and how it can be amended to promote vigour. This article describes how a philosophical approach known as permaculture was used to design science and sustainability learning experiences for a science class of 14-year-olds in New Zealand, based on examples of local organic food production.

Permaculture and Environmental Education: Shared Roots and Assumptions

In many ways, permaculture and environmental education are two peas in a pod. However, a search of environmental education literature for programs involving permaculture reveals little, despite the fact that the movements have developed side by side for over three decades. They share common roots in the 1970s, as well as a number of basic assumptions. Permaculture co-founder David Holmgren (2002) identifies five assumptions underlying the ecological design system he developed in cooperation with Bill Mollison. As described below, three of these assumptions are closely aligned with the assumptions underlying environmental education (UNESCO-UNEP, 1978) and sustainability (WCED, 1987):

- The environmental crisis is real and of a magnitude that will certainly transform modern global industrial society beyond recognition. In the process, the well-being and even survival of the world's expanding population is directly threatened;
- The ongoing and future impacts of global industrial society and human numbers on the world's wondrous biodiversity are assumed to be far greater than the massive changes of the last few hundred years; and
- Humans, although unusual within the natural world, are subject to the same scientific (energy) laws that govern the material universe, including the evolution of life. (Holmgren, 2002, pp. xv–xvi)

Unlike the development of permaculture, which was largely the vision of Holmgren and Mollison, environmental education was shaped during the 1970s by a series of international summits and reports. With additional summits and reports over subsequent decades, the emphasis of environmental education shifted toward the type of sustainability thinking embraced by permaculture from its beginning. What Orr (1992) described as an ecologically literate citizen two decades ago easily describes a practising permaculturist. This is not to say that permaculture has not also developed over time. Just as environmental education (EE) branched into differing approaches, such as education for sustainable development (ESD) and education for sustainability (EfS), permaculture has taken on two similar but distinct interpretations (Whitefield, 2010).

Original Versus Design Permaculture

Permaculture emerged in the mid 1970s through the work of Mollison and Holmgren. Mollison, tired of protesting *against* environmental degradation, was determined to develop a positive, solution-oriented approach *for* environmental protection (Mollison, 1988), with a focus on sustainable food production. The word *permaculture* was formed from the words *permanent* and *agriculture*, which represents an emphasis on perennial crops over annuals. Another emphasis was mimicking nature in biologically diverse food systems as alternatives to monocultures. For example, the commonly recognised permaculture interpretation of an orchard is a food forest, where a chemically managed monoculture is replaced by an organic polyculture. Early writings on permaculture (see

Mollison, 1988; Mollison & Holmgren, 1978) focused on such low-input/high productivity food systems, sometimes called *cultivated ecologies* (Mollison, 1991). Whitefield (2010) calls this overt focus on food production *original permaculture*, and differentiates it from an evolved and broader interpretation he calls *design permaculture*.

Design permaculture has emerged over the last three decades to address more than permaculture's agricultural applications (Whitefield, 2010), as the original vision of *permanent agriculture* evolved into one of *permanent culture* (Holmgren, 2002). The design principles developed by Mollison and Holmgren are broad enough to apply to many cultural systems, such as legal, financial and business (Hopkins, 2008). Holmgren (2002) includes the built environment, tools and technology, culture and education, health and spiritual wellbeing, finance and economics, and community governance within the scope of permaculture design. In this study, we used a *design permaculture* perspective on teaching and learning.

Although a widely accepted definition of permaculture has been elusive, it can be described as a system of design that seeks to recognise and maximise beneficial relationships while minimising or eliminating harmful relationships (Lebo, 2012). This was the overall design perspective throughout our study. For example, within the context of science and sustainability learning, potential beneficial relationships explored were those between EE, science education, and permaculture itself.

Such designing in threes is common practice in *original permaculture*. When three different plants are placed together with the intention that each benefits the others, permaculturists call it a *guild*. One well-known guild consists of corn, beans and squash — the Hopi 'Three Sisters' from the American Southwest. From an educational perspective, cultivating a relationship between environmental education, science education, and permaculture creates a *learning guild*, building on the already recognised mutualistic relationship between environmental education and science education (Gough, 2004; Steele, 2011).

This is an example of *design permaculture* thinking as it translates the original food-focused design intention to a non-food production context. Additionally, in this learning guild, original permaculture examples of food production were used to promote and enhance students' engagement in science and sustainability learning, just as legumes are used to improve the growth and productivity of companion plants. In other words, the study used design permaculture to focus on science and sustainability learning *through* food production. This type of pedagogical approach aligns with what Holbrook and Rannikmae (2009) argue is the best way to teach scientific literacy: 'education through science' instead of 'science through education'. In the same way, this study advocates 'science education through permaculture' rather than 'permaculture through science education' (Lebo, 2012).

The Intervention: Food as a Context for Science and Sustainability Learning

If viewed as an exercise in design, the challenge in this study was to engage students in science and sustainability learning while maintaining allegiance to the New Zealand Curriculum (Ministry of Education, 2007). From a design permaculture perspective, the inclusion of environmental education and permaculture would have to enhance the teaching and learning of science, not detract from it. The process of engaging students in science and sustainability learning involved two mutually reinforcing strategies throughout the intervention: *cultivating attitudes* toward science, learning science, and the environment; and *trellising* science and sustainability learning. These strategies are explained further in the discussion section.

The intervention was composed of three units — Environmental Chemistry (including the topic of global climate change), Ecological Principles, and Plants for

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Food — arranged with the intention of promoting transformative learning in students. This *transformative chronology* (Lebo, 2012) was designed to align with the process of transformative learning (Mezirow, 2000), and to mimic permaculture co-founder Bill Mollison's own transformation as he described it in the documentary, *Global Gardener* (Russell & Gailey, 1991). In brief, this view of transformation involves a disorienting dilemma (Mezirow, 2000), followed by an examination of other perspectives, and ultimately the adoption of an alternative worldview. In this instance, that worldview can be described as ecological literacy, which includes science and sustainability knowledge, an attitude of care for the environment, and the tendency to act on that knowledge and those feelings (Orr, 1992).

The topic of global climate change was placed first to serve as a potential disorienting dilemma for students, as it represents an urgent threat to humanity (IPCC, 2007). The unit on ecology was placed second to engage students in the examination of how natural ecosystems tend toward dynamic stability and resilience to volatility by relying on diversity and negative feedback loops. Finally, the food unit was placed third to expose students to certain original permaculture practices that exhibit ecological design (lessons from observing nature) to enhance the productivity and resilience of food systems.

Through studying these units in this order, it was hoped that students would develop an understanding of sustainable food production in their community as one way to address environmental issues such as climate change. In other words, the learning opportunities would take on a heightened level of relevance coming at the end of the transformative chronology. Relevant learning contexts are important for promoting scientific literacy (Holbrook & Rannikmae, 2009; Keller, 1983) and ecological literacy (Balgopal & Wallace, 2009; Orr, 1992).

Using Local, Sustainable Food Production

Of the many lessons involved in the intervention, there were several teaching and learning activities directly related to local, sustainable food production. Included in those were two field trips that took place during the latter half of the intervention: one to a food forest near the school, and the other to an eco-accommodation several kilometres away.

The first field trip was to a food forest in a suburban park 1 kilometre from the school that was planted a few years earlier by a group of local permaculturists. It consisted of approximately 20 fruit trees planted in two equal clusters covering about 30 square metres each. Both of the amoeba-shaped clusters were sheet mulched with corrugated cardboard and woodchips. A range of fruit types and cultivars grew through the mulch, and there was evidence of a diverse groundcover taking hold in places. The field trip was placed at the juncture of the Ecological Principles and Plants for Food units, and was meant to serve as a transition for students from their ecology learning to their ecological farming learning — making connections between the two and providing a local context. The main science topics addressed at the food forest were biological diversity, predator/prey relationships, and soil permeability. Sustainability topics included issues such as 'food miles', chemical use in agriculture, and the 'carbon footprint' of food. The field trip was designed to be student-centred, allowing them to build on previous learning by working in groups and asking questions of the site host.

The field trip to the eco-accommodation — referred to henceforth as Eco-Hostel — took place near the end of the final unit. The 10-acre property was located 7 kilometres from the school, and the owners were developing it into a permaculture site complete with energy-efficient dwellings, water conservation methods, composting, and fruit and vegetable production. After an introduction that tied together students' previous learning on climate change and ecological principles using a large concept map, the students were shown four sites on the property that exhibited how science knowledge can be used for sustainable food production. Those sites were: a water-retaining swale planted with feijoa trees (a fruit tree); a chicken tractor using poultry to clear land for a future garden; a hot compost pile; and a biologically diverse organic garden. At each of these stations students were encouraged to ask questions and to explain the science behind these common original permaculture practices. We also revisited 'food miles', chemical inputs, and 'carbon footprints'.

Methodology

This study was conducted with one male mid-career science teacher, who indicated he had no previous knowledge of permaculture, and a class of 18 14-year-old students in a mixed-race small secondary school. Research into impacts of the intervention took the form of an interpretive, mixed methods case study that sought to understand how the teacher and his students made sense of their world. Data collection, which included the use of questionnaires, interviews and observations, focused on the impacts of a permaculture approach on the teaching and learning of science, on students' ecological literacy, and on students' attitudes toward learning science in school. Pre- and post-intervention questionnaires probed students' opinions on the environment, science, and learning science in school, and examined their sustainable thinking with concept mapping exercises (Novak & Musonda, 1991). Regarding the latter, identical exercises on both questionnaires asked students to make concept maps showing what they knew about a sustainable system for producing food. Quantitative data were gathered in the questionnaires but as the student sample size was small, this data is indicative only. It was analysed using simple descriptive statistics methods and in some cases, rubrics based on sustainability designed for the study (these and the corresponding data are discussed below).

Participant observations of the class took place over the course of 12 weeks, on average 3 days per week, totalling 31 days. One of us took the role of participant observer at times during the study, particularly during the field trips, as this person is an experienced science teacher and practising permaculturist, features which were clearly declared to the teacher and students at the outset. Before and after some classroom visits, the observer had informal conversations with the teacher, along with three more formal interviews before, during and after the intervention. Three focus groups of students were held immediately following the intervention.

Analysis of qualitative data from the observations and interviews was mainly inductive, which can be likened to the permaculture practice of designing from pattern to detail (Holmgren, 2002), and contributes to theory generation. The process of analysing from pattern to detail was particularly enhanced by prolonged engagement with the class, allowing an interactional, holistic view of the data to emerge. As the focus group interviews took place after 12 weeks of classroom observations, they provided a series of 'light bulb moments' as we identified patterns and themes emerging from the data the students were providing. The sense they were making of their science lessons, their permaculture experiences, and the transformative chronology of the three units was triangulated with the data from classroom observations, data from the teacher gathered through interviews and informal conversations, and the pre- and post-questionnaires. Data themes were coded manually and then clustered into groups that were examined and peer reviewed. These themes were subjected to negative case analysis before full coding was completed. Themes and patterns emerged in two dimensions, which we identified as vertical (within-case analysis) and horizontal (cross-case analysis). The vertical dimension represented the specificity and consistency of meanings of experiences for each student. The horizontal dimension represented the diversity and generality of meanings expressed across the student cohort.

Findings

While food production was only one aspect of the design permaculture approach in the science class, findings indicate it was impactful on students and the teacher. Findings are presented in two sections below that describe some of the apparent impacts of the unit on food production on the attitudes and learning of both students and the teacher.

Impacts on Students

As described above, the unit on food production was the third of three units designed to cultivate a heightened level of relevance for students with regard to science and sustainability learning. Data on student learning experiences provided some evidence of the cultivation of positive attitudes towards science and sustainability. 'I think it was fun, so we remembered what we did,' one boy said of the field trips during a focus group interview after the intervention. In another focus group interview, one girl reported what she remembered most about the intervention: 'When we went down to that garden. That was real memorable.'

Most students reported to enjoy learning science with a focus on the environment in the post-questionnaire. On a 5-point Likert-scale where 5 equalled *strongly agree*, the class mean was 3.5 with a standard deviation of 0.7. Many students reported favourably on the field trips, emphasising their experiential nature. One boy said he liked them because 'We actually got out doing stuff instead of just sitting in the class learning about what other people are doing' (Focus group interview). Experiential learning is often used as a way to engage students (Daudi & Heimlich, 2002; Tilbury, 1995), although at times there may appear to be no clear boundary between relevance and engagement, because they can relate to and reinforce one another. For instance, during one focus group interview after the intervention, a group of three boys spoke enthusiastically about both the experiential and contextual aspects of the field trip to Eco-Hostel simultaneously. Following the statements above on 'fun' and 'doing stuff,' another boy — citing the permaculture practices of mulching with vegetative matter and companion planting — said, 'Yeah, learning about how the garden works, instead of buying the weed killer and stuff, that there are other plants that can stop it [weed competition] instead.'

This may indicate the synergistic, or regenerative, impact of learning within the context of local sustainable food production. In other words, relevance can engage students, and engagement (through hands-on approaches) can help promote relevance.

Many students reported they recognised certain science and sustainability topics from their classroom learning on the field trips, such as seed types and germination, soils and compaction, and biological diversity (Focus group interviews). On a 5-point Likert-scale where 5 equalled *strongly agree*, all 16 students who attended the field trip to Eco-Hostel agreed or strongly agreed with the following two statements on the post questionnaire: 'The field trip to Eco-Hostel helped me see permaculture in action', and 'Permaculture is a good way to solve environmental problems'. Of the students who attended the field trip to the food forest, half (8/16) agreed and the other half were neutral about the following Likert statement: 'The field trip helped me learn about environmental projects in my community.' These findings appear to indicate that students recognised the relevant contexts — primarily sustainable food production — provided by the field trips.

Garden-based learning has been identified as providing real contexts that allow valuable opportunities for knowledge construction, higher order thinking, and the development of analytical and synthesis skills (Hayzlett, 2004; Miller, 2007; Subramaniam, 2002). Miller (2007) contends that gardens are an effective context to teach about sustainability theory through examples of sustainable practices supported by environmental science and ecology. Driscoll and Lownds (2007) used extended field trips to a garden site to foster wonder and curiosity in primary school children. Although this study included secondary students, there were elements of wonder and curiosity alongside an appreciation of relevant contexts. For example, some students expressed amazement when first seeing steam rise from a compost heap. Others said they were surprised by the use of chickens to prepare garden beds, and the use of companion planting to reduce insect pest damage; as one said, 'Knowing how different plants can coincide with each other … instead of using bug spray' (Focus group interview). One boy in particular was fascinated by the use of swales to reduce surface water runoff and increase infiltration. The trip to Eco-Hostel provided fertile grounds to cultivate students' attitudes toward science and sustainability learning by providing a local context in which the two worked hand-in-glove, and to trellis learning by sowing a wide variety of examples and allowing students to ask questions about those which most intrigued them.

Two girls identified organic gardening as something they had learned during the intervention. One admitted, 'I didn't really know there was another way of gardening' (Focus group interview). The other added, 'I heard about it, but I didn't really understand it' (Focus group interview). Regarding the recognition of ecological possibilities, this appears to be a milestone for both learners. Knowing that it is possible to grow vegetables without purchased artificial chemical applications is the first step toward learning how to do it and then perhaps one day doing it.

The relevance and engagement provided by the field trips may have been particularly impactful on six students who reported not to enjoy learning science in school on the pre-questionnaire. Although they reported the same on the post-questionnaire, five of them agreed or were neutral in response to the Likert statement 'I enjoyed learning science with a focus on the environment'. (These students — who appear to have disengaged with science during their schooling — are discussed further below.) Any apparent changes in attitudes toward science and learning science were not accompanied by clear evidence of changes in attitudes toward the environment. Data were mixed between the questionnaires, observations and focus group interviews. For those students who reported to enjoy learning science in school on the pre-questionnaire, the data indicated no change in attitude in the post-questionnaire.

While relevance and engagement may go together like peas and carrots, science learning and sustainability learning may be equally complementary within the context of original permaculture food production. In this study we used identical concept mapping exercises on the pre- and post-questionnaires to assess some aspects of students' science and sustainability knowledge and, in particular, systems thinking. The exercises provided 16 terms in a word bank and asked students to make a concept map showing what they knew about a sustainable system for producing food, using any additional terms they thought might apply. When analysed against a framework of permaculture principles, overall word use that aligned with these principles increased slightly between the pre- (*M* 11.5 words, *SD* 4) and post-questionnaires (*M* 12.1, *SD* 4), and three students added their own words to their post-maps: soil, legumes, shops, pollution, and people.

For the purposes of evaluating students' recognition of sustainable and unsustainable practices in food production, we developed a process for scoring *sustainable propositions*. Put succinctly, two concept words connected by a linking word or phrase form a proposition. For example, the terms *food* and *organic* can be connected by the phrase 'can be', forming the proposition: food can be organic. A proposition is a unit of meaning assembled in cognitive structure. Each proposition was analysed for whether or not it trended toward sustainability. Only those propositions that were considered to reflect sustainable thinking were counted. Potential sustainability-related issues that students could have identified included: the use of fossil fuels (both on farm and in transportation — 'food miles'), soil fertility, insect and weed control, meat-centred diet (eating lower on the food chain), and water conservation. While the class mean for sustainable propositions improved (1.8 to 2.2), an increase in standard deviation (1.4 to 2.2) suggests some students experienced growth in their sustainability learning while others did not.

Impacts on the Teacher

During the final interview in this study, the teacher reflected on what he identified as 'a positiveness in that class', particularly after the trip to Eco-Hostel. But he admitted, 'I can't really tie it down to anything specific.'

Like any living ecology, a learning ecology is complex and multifaceted. As described above, the relationship between relevance and engagement appeared to be dynamic and mutually reinforcing for students, especially during the unit on food production. Additionally, the teacher was aware of the role that this unit played as the final step of the *transformative chronology* (Lebo, 2012).

During the early stages of negotiation about the intervention, the teacher expressed no concern about reordering the units. He recognised that this simple manoeuvre would not cause extra work for him or disrupt the overall curriculum in any significant way. Months later, during the final interview, he reflected on the progression of the units by describing them as moving from the big picture to a more detailed perspective: 'It's logical. I do think that was better than going in and teaching about seed germination at the start. That's just basically science-learning names. But this wasn't. This was a whole crazy interwoven web of science: a good idea.' By referring to the transformative chronology as 'logical', 'better', and 'a good idea', the teacher appears to be expressing his appreciation for one component of what he also called 'a new way of teaching science: It's about making it relevant, global and it's passionate.' This expression of appreciation for something new appears to indicate that the teacher experienced learning about science teaching and learning, and that his perspective changed as a result.

The passages above may be said to hold special significance because the teacher was not sold on the idea of a permaculture approach from the beginning. During the negotiation he was not specific about what his reservations were, simply stating that he had them, but was 'willing to give it a go'. What might be called his cautious scepticism continued during the early stages of the intervention, but he was never clear about the particulars at the time. It was not until afterward that he shared what might have been on his mind.

> *You were the scientist coming in. You weren't some hippy permaculturist, idealist, ecologist. And I think that is what was so important for me. If that was what permaculture was I wouldn't be interested in it.*

The teacher's acknowledged lack of familiarity with permaculture appears to have been significant in shaping his initial attitude.

As the teacher became reassured that permaculture had an adherence to science he began commenting on the ways in which a permaculture approach appeared to engage his students. For example, after the field trip to the food forest he said, 'I think it was good to get the students out there seeing that project in their community.' As a context for learning, the teacher praised the role of permaculture food production in promoting the *relevance* of science learning, and its ability to *engage* students. He was particularly impressed by the field trips run by one of us as part of the intervention:

> *The field trips worked real well. That was because it could be seen as something real and not just something talked about in the laboratory. Especially at Eco-Hostel and at the food forest as well: the activities making it real to that person.*

The teacher went on to reflect on other activities, but then returned to the field trips, saying, 'So the field trips I guess was the greatest one. I suppose that's a big thing at the moment — trying to make it relevant.'

During informal conversations throughout the intervention the teacher did not make statements specifically about relevance, but did comment with increasing frequency on student engagement. For example, he said that one boy had 'cottoned on' to the idea of using swales to manage water at Eco-Hostel. He made a similar comment during the final interview: 'That water system struck a chord. "Edward" asked if we could do that again, or build one.'

In these passages, the teacher emphasises *real settings* and *relevance*. Although other approaches to making science relevant were included during the intervention, it appears that the teacher felt the field trips were a particularly effective means to achieving that end. Relevance has been recognised as important for promoting both scientific literacy (Holbrook & Rannikmae, 2009; Keller, 1983) and ecological literacy (Balgopal & Wallace, 2009; Orr, 1992). When asked if he would teach the three units with the same activities in the future, he replied:

> *Yeah, I'll be using these. I'll be using permaculture more across the board, and if I review my biology units they'll be better served as a permaculture interconnected unit. Biology is seen as the science of learning names but permaculture is the science of process.*

Although it would be an overstatement to say that the teacher changed his perspective on science and sustainability education through his participation in this study, evidence suggests a number of ideas for engaging students took root.

Alongside relevance and engagement, the teacher identified the importance of the participant researcher's role as citizen scientist and permaculture More Knowledgeable Other (MKO). According to social development theory (Vygotsky, 1978), children working at any stage of cognitive development may be able to operate at a higher cognitive level by interacting with a MKO. During the final interview, he said, 'I think your character went well with that. You were the scientist coming in. You weren't like some hippy.' Mayer-Smith, Bartosh, and Peterat (2007) found that pairing children and elders in the context of gardening resulted in changes to the children's personal relationships with the environment:

> *Working side-by-side with experienced farmers and gardeners who are community elders, the children are able to experience a world outside of their school that supports and encourages learning. (p. 83)*

These researchers also report that an intergenerational context — which can be likened to Vygotsky's MKO — provides a social setting that supports the growth of what Morris (2002) calls environmental consciousness. The notion of *growing* consciousness instead of *building* it is explored next.

Discussion: Is Learning Built or Does It Grow?

When engaging students in social construction, Bruner (1986), among others, recommend scaffolding, an instructional theory developed out of Vygotsky's work in social development theory that focuses on the socio-cultural contexts in which learners interact in shared experiences such as the field trips described above. Scaffolding requires an MKO in the context of shared social learning, an arrangement that can promote transformation (Mayer-Smith, Bartosh, & Peterat, 2007). Although these elements were present in the design of the intervention, when finding ourselves standing with students in the middle of a thriving garden, the image of a scaffold appeared inadequate to describe the organic growing and learning surrounding us. In other words, the processes of growing an environmental consciousness (Morris, 2002) cannot be compared to constructing an office building.

The term *scaffolding* falls short in two crucial ways. First, a scaffold is erected in order to build a structure that has already been planned down to the last detail. With exacting specifications, the building takes form within the prescribed boundaries of the scaffold. In keeping with the context of growing food, we prefer the agricultural image of a trellis instead of the mechanical image of a scaffold. A trellis cooperates with growth by providing a suggestion of where to grow, along with support, rather than a rigid prescription for exactly what growth should be. Where a scaffold constrains the subject within a framework, a trellis allows the subject to *engage with* the framework on its own terms: to weave in and out, branch laterally, or even reach out and grow on to another trellis. The distinction between trellising and scaffolding is critical because if permaculturists erect restrictive frameworks, teachers may be less likely to partner with them for learning opportunities. Findings from this inquiry suggest that some impacts on the teaching and learning of science may have resulted from using permaculture as a trellis rather than a scaffold, because some of the growth experienced by the teacher and students was responsive rather than prescriptive. As described above, the teacher responded favourably to some of the pedagogical practices that *he had chosen* to incorporate, based on our suggestions and unit plans. (The teacher's experience will be explored further in a forthcoming article.) In the same way, growth in students' science and sustainability learning may have been nurtured by the opportunities to observe science in a different way, more relevant to their lives. As Sterling (2001) argues, for learning to be sustainable, it must be owned by the learner. We believe this to be particularly true of the types of learning central to sustainability education: learning to think; learning to care; learning to act.

The other shortcoming of the 'scaffold' imagery is that buildings are only as strong as their foundations. Scaffolding is erected after a foundation is poured, meeting specific requirements for strength. In the field of education, the terms *good foundation* and *poor foundation* are used to describe students' prior learning. While we agree that these are fair terms when describing content knowledge and skill sets, they fall short when addressing attitudes toward learning. For example, a student may have a good foundation in chemistry, but a poor attitude toward learning chemistry in school may hold him or her back. Declining student engagement in school science is a concern worldwide (Tytler et al., 2008).

The quality of learning, to a certain extent, depends on a learner's attitude. But attitude cannot be poured like a foundation of concrete and steel, it must be nurtured, or, to use another agricultural term, *cultivated*. In a garden, cultivating soil means creating the best conditions for growth. While cultivation can result in healthy plants that stand on their own, many gardeners erect trellises to support and maximise vertical growth. As with trellising, we believe cultivating positive attitudes toward

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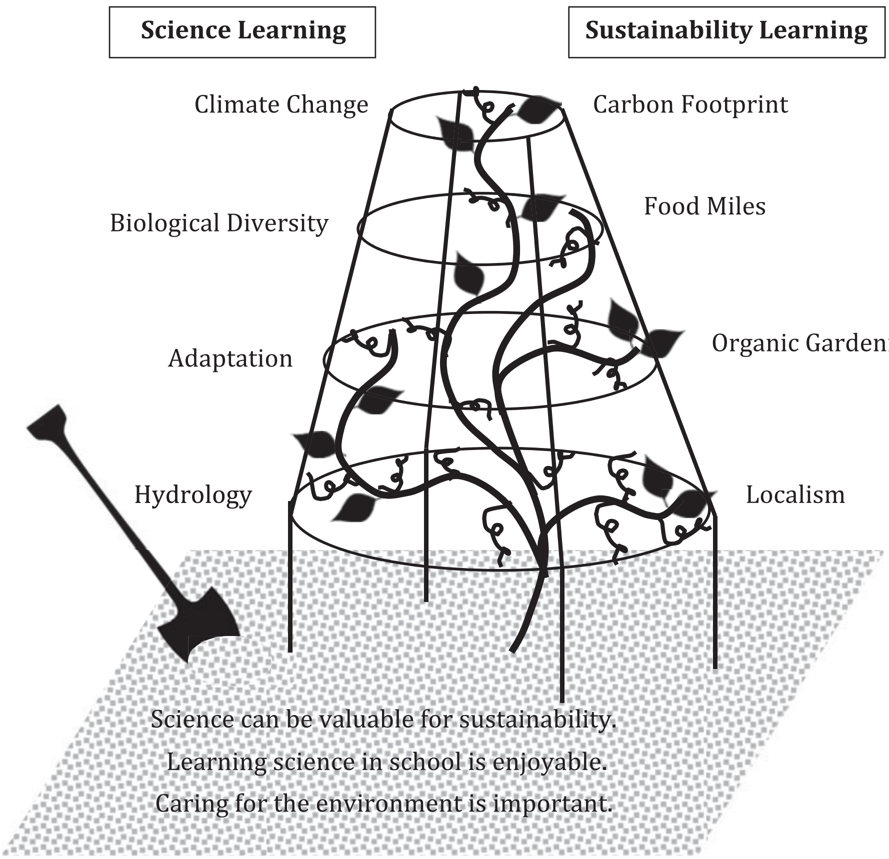

FIGURE 1: Cultivating attitudes and trellising learning.

sustainability learning is particularly important. As described above, findings indicate that the context of permaculture food production can help improve some students' attitudes toward science, and toward learning science in school, but were mixed on influencing students' attitudes toward the environment. Observations of students during class as well as their own voices during focus group interviews supported findings of the pre- and post-questionnaires indicating positive or neutral responses to learning science in a permaculture context. As seen in Figure 1, we engaged in an approach of *cultivating attitudes* and *trellising learning*.

When imaging how students learn, are the minds of students more akin to buildings being constructed, or to plants, needing nurturing and support in ways best for each? Some vegetable plants, such as beans and peas, will grow up a trellis on their own using tendrils, but others, such as tomatoes, benefit from more hands-on involvement to support vertical growth, or even pruning to improve vigour and productivity. Likewise, some students will inevitably learn on their own while others need extra support, or perhaps even the pruning away of barriers to learning, such as negative attitudes or alternative conceptions.

This study found students across this spectrum. The students who reported they enjoyed learning science in school before the intervention reported the same after the intervention. Like climbing beans or sweet peas, these students appear to have the ability to support their own growth across a wide range of science learning experiences.

However, as described in the findings section, most of those students who indicated they did not enjoy learning science in school responded positively to the relevant, experiential and sustainability aspects of the food-based field trips. Like tomato plants, these students appeared to benefit from cultivation and trellising.

One of the unique functions of permaculture is to restore overused, degraded or damaged landscapes that suffer from compacted soils and excess surface water runoff. Along those lines, findings from this study appear to indicate that a permaculture approach may have the potential to restore interest and motivation to learn in some students who have disengaged with science learning over years of schooling. One original permaculture technique commonly used to break through compacted soils and rehydrate the earth is chisel plowing. In cases where intensive animal herding or heavy machinery have severely compressed soils beyond their ability to readily absorb water, a chisel plow is used to mechanically aerate the earth without overturning it like a traditional plow. This form of low-impact cultivation returns air and water to previously compacted soils. Since air and water are essential to life, soil biota is encouraged, which further aerates the soil in a positive feedback loop: the presence of life creates conditions that favour more life.

This is a prime example of the regenerative nature of original permaculture and what this intervention sought to mimic using design permaculture thinking applied to those students hardened against science learning. Specifically, cultivating more positive attitudes toward learning science using the context of local, sustainable food production can lead to growth in scientific and ecological literacy, which can lead to even more positive feelings toward learning science, as well as toward the environment and toward science itself in a regenerative, upward spiral.

But for these students, all of the trellising in the world will not help unless it is accompanied by gentle cultivation. While pedagogical chisel plowing appears beneficial for this cohort, it is simply redundant for students who already enjoy learning science in school. However, for these students, cultivating positive attitudes toward the environment can help stimulate growth in sustainability learning. As described above, a learning guild consisting of elements of environmental education, science education and permaculture was designed to produce multiple yields, as shown in Figure 1.

In sum, this inquiry sought to create a cultivated transformative learning ecology in a science classroom with learners as diverse as corn, beans, squash and tomatoes. From our perspective, a permaculture approach to teaching and learning is front-loaded with thoughtful design, and involves the use of pre-existing elements such as local permaculture properties and practising permaculturists, but allows much of the actual learning (growth) to occur organically. In this 'field of dreams', if you design it, they will learn.

Keywords: permaculture, science education, ecological literacy, ecological design, transformation, field trips

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