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A TRANSFORMATION MINDSET FOR COMPUTING EDUCATION FOR SUSTAINABILITY

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ABSTRACT

The premise of Computing Education for Sustainability (CEfS) is examined. CEfS is described as a leverage discipline, where the handprint is much larger than the footprint. The potential of this leverage is described and the development of the field explored. Unfortunately CEfS is found not to be making sufficient impact in terms of a contribution at scale to system change actions resulting in restorative socio-ecological transformation. A transformation mindset is described that provides a lens for considering the role of CEfS and what might be done about it. Three inspirations are described - a case study of a learner with an ambitious change aspiration, a values-driven business, and an alternative approach to education: work-based professional practice education. These lead to consideration of implications, which while not exhaustive, are intended to provoke debate about the nature of computing education for sustainability.

KEYWORDS

Education, sustainability, computing, transformation

1. INTRODUCTION

The fields of education, computing and sustainability coalesce in Computing Education for Sustainability (CEfS). This can be seen as the combination of two disciplines with very high leverage, for change in a third arena - where the handprint, the potential to do good, is massively greater than the negative impact, the footprint. This CEfS should have the potential to be a significant agent for change. In this paper, however, I argue that we have largely failed in this mission, and a radical rethink is needed.

Sustainability is considered here in terms of system change actions resulting in restorative socio-ecological transformation.

2. CEfS POTENTIAL

2.1 Education

Education can be considered a leverage discipline. Our service – our potential to do good – is vastly greater than our negative impact. Education for Sustainability (EfS) is fundamental to the global Sustainable Development Goals and most, if not all tertiary organisations have begun to address the operational aspects of sustainability. Many tertiary organisations can point to some element of their curriculum that focuses on sustainability. But few have addressed EfS in a holistic, multidisciplinary and systematic manner.

Otago Polytechnic is one tertiary organisation that has at least attempted this holistic EfS. In 2007 it adopted as a core strategic objective the statement that "every graduate may think and act as sustainable practitioner". With some tweaking of the wording, it remains so in 2016 - as illustrated in the opening paragraph of Otago Polytechnic's Annual Report:

> *"Guiding our students through a formative time in their lifelong learning journeys is a special privilege. At Otago Polytechnic, they engage in an experiential learning process and emerge as capable, work-ready, future-focused and sustainable practitioners".*

The Otago Polytechnic sustainability journey is explored in The Green Graduate (Mann 2011) and The Simple Pledge (Mann and Ellwood 2009). Rather than specifying a pre-determined set of behaviours to describe sustainability within a discipline, instead we aim to take students on a journey of themselves identifying what it means for them to think and act as a sustainable practitioner. In 2013, 93% of graduates agreed with the statement that "my learning experience developed my understanding of social, environmental and economic sustainability". In the Graduate Employer Survey (2012 data), 94% of employers rated "Demonstrate an understanding of social, environmental and economic sustainability" as a criteria for employment as very high, high or moderate, and 87% agreed that Otago Polytechnic graduates demonstrated this attribute. In 2013, the international benchmark AUSSE survey asked respondents to rate the learning experience on a number of dimensions, including "the learning experience…contributes to living in a sustainable way". Otago Polytechnic respondents were considerably more agreeable than the benchmark (58% agree, national and international benchmark groups both 35% agree).

2.2 Computing

Computing also has the promise of being a leverage discipline. Despite a very large and troubling footprint, the potential handprint of computing is far greater.

Computing's footprint is indeed troubling. Even if we just consider climate change (and we shouldn't as sustainability is very much wider than that, but energy and carbon are useful proxies), computing's infrastructure contributes about 2% of anthropogenic greenhouse gas emissions (Preist and Mann 2013, Raghaven and Mann, 2016) - about that of the aviation industry.

This problem is huge and we need to do everything we can to reduce this burden on the planet. But our potential handprint is bigger, much bigger. If we just consider climate change (again noting the qualification on this narrowing), Skip Laitner estimates that our society runs on about 14% energy efficiency "we are wasting most of what we produce"

(Laitner *et al.* 2014). While not the only solution – we need to consume less too – a big chunk of the gain Laitner describes can only come from ICT enabled systems improvements, perhaps as much as 30-40%.

2.3 CEfS

So, education has a high potential leverage, and computing has a high potential leverage. The potential for combining them as Computing Education for Sustainability (CEfS) is very appealing. In terms of making a difference - contributing to a socio-ecological transformation, this could make a big impact.

In practice, Otago Polytechnic's computing degree has seen a wide variety of sustainability related capstone projects performed for industry "client" partners.

- An app for managing wildlife interactions on beaches
- A device for mapping cycle-traffic "near miss" passing interactions
- A local food cooperative
- A home-based solar power management
- An electric vehicle control system
- A hybrid physical and digital social enterprise education game
- A support system for disadvantaged and vulnerable learners
- A game for teaching sustainability via a farming simulation.
- A game for teaching peace and conflict resolution
- A system for supporting distributed funding for charities
- A management system for reusing eWaste
- A food footprint calculator
- A source map for local food
- A citizen science based tool for rocky shore environments.

Sustainability is not a requirement for the capstone, but it is interesting to note that in their last major projects, and without a requirement, students are seeing this area as a useful vehicle for integrating skills learnt in the degree and that industry clients are seeing value in these projects.

In 2007, we began a series of papers on an agenda for computing education for sustainability. We first linked sustainability and computing, quoting United Nations Secretary-General Ban Ki-Moon who argued that that "information and communications technologies (ICT) are crucial in spurring development, dignity and peace". He argued that we should "turn the digital divide into digital opportunity" and that ICT should be promoted "in fighting poverty, illiteracy and disease, in protecting the environment and empowering women and girls". We stated that "as computing professionals we need to examine what role we see computing professionals playing in that future. As computing educators charged with creating those computing professionals we are doubly responsible, as we also have put in place the system to get us there" (Mann and Smith 2007a). In Mann and Smith (2007b) we took up this challenge and described the drivers for an emergent field of Computing Education for Sustainability. We explored options for including sustainability in computing qualifications. We looked for, but couldn't find whole degrees in Sustainable Computing, indeed whole courses were similarly elusive. Our preferred approach was one of "critical inquiry and integration throughout the curriculum in ways that are both incremental and transformative" (2007a).

The paper (Mann and Smith 2007b) concluded with a suggested agenda for developing CEfS. After further workshopping at a national conference, an agenda was agreed by the National Advisory Committee on Computing Qualifications (NACCQ). NACCQ (then its successor organisation CITRENZ) added sustainable practice to all computing qualifications. Most recently, in 2013-2015, all sub-degree computing qualifications were completely rewritten in government mandated review. All such New Zealand computing qualifications now include explicit requirements for sustainable practitioners in the graduate profile outcomes. On an international level, a series of workshops at ACM's ITiCSE conference (Mann *et al.* 2008, Mann *et al.* 2009, Goldweber *et al.* 2013) brought CEfS to the attention of international computing educators. The eventual outcome of this was the recognition of the sustainable practitioner in the ACM CS2013 Core Curriculum as a Core Tier 1: "Identify ways to be a sustainable practitioner".

3. TRANSFORMATION MINDSET

Mann *et al.* (2017) introduced a Transformation Mindset (Figure 1). A transformation mindset is defined as a way of thinking that leads to transformational acts resulting in socio-ecological restoration. This transformational focus comes from Olsson *et al.* (2004) who argued that "what is now needed is nothing short of major transformation—not only in our policies and technologies, but in our modes of innovation themselves—to enable us to navigate turbulence and meet Sustainable Development Goals".

The mindset can be considered with a device recognisable to those familiar with Software Engineering's Agile Manifesto - a list of values and attributes arranged so that each is defined in part by an opposing value. The agile manifesto structure finishes with "that is, while we value the items on the right, we value those on the left more". These things on the right then are not inherently wrong - we could find people attempting sustainability doing those things, but we argue that the things on the left are better. Hence, for example Item 7 "Values change over behaviour modification" can be read as "we value things that modify behaviours, but value change (and hence behaviour) is stronger". Most of these items also carry more than one message. Item 7, for example again, also speaks to the problem of change by appealing to inappropriate values such as promoting "green" actions because it is cheaper rather than because it is the right thing to do (otherwise, what happens when green turns out to be more expensive?). While each item can be considered separately, they are not exclusive and tensions between the items provide much of the challenge.

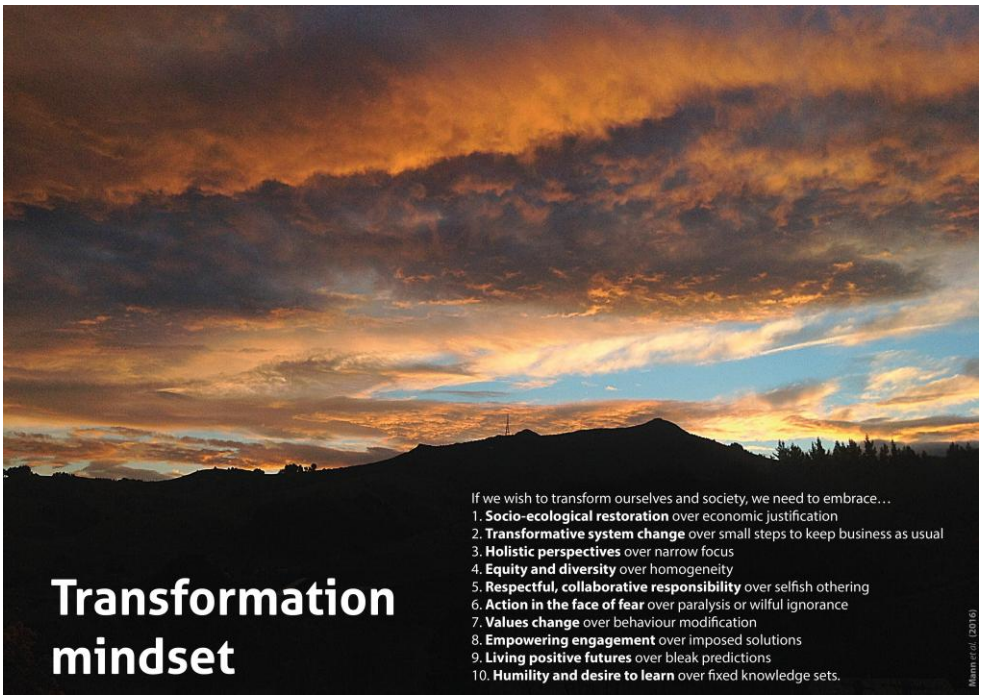

Figure 1. Transformation Mindset

If we wish to transform ourselves and society, we need to embrace…
1. **Socio-ecological restoration** over economic justification
2. **Transformative system change** over small steps to keep business as usual
3. **Holistic perspectives** over narrow focus
4. **Equity and diversity** over homogeneity
5. **Respectful, collaborative responsibility** over selfish othering
6. **Action in the face of fear** over paralysis or wilful ignorance
7. **Values change** over behaviour modification
8. **Empowering engagement** over imposed solutions
9. **Living positive futures** over bleak predictions
10. **Humility and desire to learn** over fixed knowledge sets.

1. Socio-ecological restoration over economic justification

This item makes clear that the point of sustainability is socio-ecological restoration. "Socio-ecological" is a deliberate modification of Olsson *et al.*'s (2004) "social-ecological" to bring it in line with integrated constructs such as "socio-economic". "Restoration", meanwhile is both an acknowledgment of the current path of degradation and a commitment to repair, not just stablise or maintain in a degraded state. Economic development or reasoning is not dismissed but should be seen means to achieve benefits in social, cultural and environmental aspects - a vehicle for sustainability, not a goal in itself (this aligns with Daly's Strong Sustainability, 1996).

2. **Transformative system change** over small steps to keep business as usual

Transformation is used here to move the focus beyond the comfortable perception that global environmental challenges can be met through marginal lifestyle changes (Placet *et al.* 2005), instead we need urgent and ambitious changes (Thøgersen 2009). Instead of solely working on small things and hoping that they add up to a change (themselves or with "spillover"), we need to focus on things that multiply to create positive system change. Schendler (2009) argues that we all need to be change agents. This is more than making changes for oneself. Schendler maintains that our challenges will not be solved merely by motivated individuals addressing their own footprint.

While looking for system changes, we need to be careful not to put too much reliance on "miracle cures". Waiting for technology to deliver efficiency gains through behaviour change, or even not having to change behaviour, is what Krumdieck (2015) refers to as a green myth. It's the miracle just around the corner so we can carry on business as usual.

3. **Holistic perspectives** over narrow focus

This item refers to bigger picture thinking – sustainability requires a systems approach (Svanström *et al.* 2008). People need to have awareness that their actions will have impacts. These impacts may be intended and unintended, across scales: temporal, spatial, social, and have positive and negative effects. They need to understand forms of relationships (hierarchies, partnerships, feedback) and that humans form part of a complex web. Systemic thinking emphasizes patterns, trends and feedback loops. Sustainability can be described as ethics extended in space and time. This wider ethics calls for solidarity with the entire Earth, ecological sustainability, lifestyles of sufficiency, and a more participatory politics. The underlying force of sustainability as a concept is intergenerational equity but this is largely overlooked - our time spans of concern are almost always far too short.

4. **Equity and diversity** over homogeneity

For Fagan (2009), the ethical imperative is the basis of sustainability: "To live a particular lifestyle that, knowingly, impacts detrimentally on a neighbour – be that an individual living in the next house – or a country in the next Region, cannot, arguably, be tolerated. To know of poverty in the economically developing world and not use that knowledge to act to relieve it, could be considered unethical".

The Transformation Mindset values diversity. This applies to societies, biologies and voices. The call for diversity can be seen to be in tension with the need to transform to sustainability at scale. But it does not mean a homogenous one size fits all solution. Pita Tipene (2016), a leader in Ngati Hine describes this well: "I think that we're all seeking to be a global community and to be truly global we need to both cultivate, strengthen and enhance the small villages that we have throughout the world. To retain that uniqueness and unity through diversity as a key".

5. **Respectful, collaborative responsibility** over selfish othering

Rather than shifting responsibility onto others, we need to accept responsibility and collaboratively address the issues together. Oxfam (in Parker *et al.* 2004) described a "global citizen" who is, amongst other things "aware of the wider world and has a sense of his or her own role as a world citizen", "outraged by social injustice" and takes responsibility for his or her actions.

6. **Action in the face of fear** over paralysis or wilful ignorance

In the face of wicked ambiguity we still need to take considered action rather than suffer paralysis by analysis or passively waiting for miracle cures. We should also avoid action linked to willful ignorance (or denial). Most if not all problems of sustainability can be

described as trying to address "wicked problems": intergenerational time scales, complex systems, multiple legitimate perspectives - that are not amenable to the short term, positivist intervention approach of most interventions. The world is beset with wicked problems, but as Read (2014) describes, "the wickedness of problems is no excuse for standing by".

7. **Values change** over behaviour modification

In order to make meaningful long term changes, there needs to be a shift in values, rather than just addressing harmful behaviours. Intervention that achieves behaviour change without corresponding values is likely to not be as effective due to dissonance felt by the individual. Sterling (2009) describes the importance of critical reflexivity - or deep questioning of assumptions. This reflexivity, or self-reflection is crucial to the transformation mindset - we need people to care. "First you have to care" argues AtKisson (2008) as the first step towards sustainability. We need to embed sustainability itself as a core cultural value of the system.

8. **Empowering engagement** over imposed solutions

Darnton *et al.* (2005) highlighted an attribute of change agency: the audience for a change intervention should not be regarded as a passive target. Instead, our change agents should be learn how to facilitate partnership approaches and instead of understanding changing behaviour as a single event, it should be viewed as an ongoing process. Seeking and reflecting on feedback is important. Thus actions should be: collaborative; participatory; equitable; open; trusting and support of ownership. Building self-reliance should be a goal.

9. **Living positive futures** over bleak predictions

Orr (1992) argued that "the study of environmental problems is an exercise in despair unless it is regarded as only a preface to the study, design, and implementation of solutions". While doom and gloom predictions can help jumpstart action, there needs to be more of a positive outlook in order to motive and capture change. We take an optimistic frame. It is easy to become negative about sustainability. To do so, however, is to miss the point. The focus of sustainability is on the solutions, not the problems. Sustainability is the solution to living beyond planetary boundaries and a finite number of resources.

10. **Desire to learn** over fixed knowledge sets

The desire to learn has several implications or variations: humility over willful ignorance: curiosity over fixed cognitive maps; challenging assumptions over accepting status quo. This then is a learning mindset: as Senge (2008) argued, everything we do is a learning opportunity.

4. WHY NOT A SUCCESS?

Unfortunately, if we view computing for sustainability and computing education for sustainability in terms of the Transformation Mindset – in terms of system change actions resulting in restorative socio-ecological transformation – little progress has been made. While we can identify small pockets of CEfS that approaches elements of the mindset, as a whole, the situation can perhaps be best described by Meyer and Nathan's "impoverished sustainability" (2016).

Stephen Stirling (2004) argues that education for sustainability must be transformative for the learner, and to achieve that, education itself must be transformed. The remainder of this paper asks the question, if we were to transform computing education for sustainability, what might it look like? I do not provide any definitive answers to this, but offer three inspirations for this reframing. The last section discusses implications in terms of the Transformation Mindset.

5. INSPIRATION 1: RIMU BODDY

Rimu Boddy is making New Zealand's Quota Management System easier to use, improving compliance, and adding value to the fishing industry (Rimu's name and story are used here with permission). He graduated with a Bachelor of Information Technology from Otago Polytechnic in 2012. Rimu was not an A+ student but he came with a very strong passion - to make a difference in the fishing industry.

Imagine the reckless swearing alcoholic rough fisherman. That's me. And still is.

Rimu was dissatisfied with the way the Quota Management System worked in practice. It was not realistic to expect fishermen to complete a complex paper form every time they put the net out. Unsurprisingly, compliance was low, as low as 15%.

I had an idea - and went to Otago Polytechnic to make it real.

I left fishing to go to Otago Polytechnic with a loose idea to use IT to do something better for fishing in terms of information flow - or something, I knew there were gaps. Rimu had an idea, that technology could be harnessed to improve the information flow, but he realised he needed to gain the skills to develop his idea. His focus during the degree was almost entirely on his idea.

Throughout each class - I asked questions directly relating to the project. This got annoying, but the tutors always answered - even when we go a bit off topic.

Business analysis was basically what the preliminary project was for me.

This was when things started to take shape.

The going was tough, both financially and academically

I had a son, had very little money saved.

I worked at nights at the newspaper - and struggled to understand Java. The bits I'd missed in the 1st year were crippling. But over time and with lots of study - the details started to sink in

Rimu's capstone project was always going to be on his fisheries system - by now referred to as "fish bucket".

I spoke to lecturers early on regarding the possibility of creating something as a third year project. The reaction was completely supportive.

3rd year project, came with much excitement.

The same core concepts I learned in the 3rd year I still apply today. Loads of public speaking - in front of the class and more was another key element.

The other half of what was needed - making something that users can actually use was all the "other work" - what I still see as the bulk of any project; that process was laid bare in the 3rd year project, the absolute messiness of it all.

During the final year of his IT degree, Rimu entered in the student business entrepreneurship competition and emerged a category winner, and eventually winning the National Business Review student business competition.

By the end of the 3rd year - scraping through a few classes I had a business model and a software model. Some lasting friendships, and - a barely working set of prototypes. And all the connections I would need to move the project into a business.

The following years, Rimu continued to work on his project with a business incubator, supplementing his income with work for other organisations, and returning to fishing.

Toward the end of that year I was hired as a tester for HPSport - through connections at the Polytech. I managed to upskill there while - working with Dunedin based Upstart to try to get the project into production with Talley's.

Underfunded and under skilled I couldn't pull it off despite Conrad Anderson's and my best efforts, we couldn't get traction.

During that time, Rimu was the client for a further BIT capstone project

Otago Polytech provided us with a student to do part of the project as a 3rd year project that went seriously well.

And the roller-coaster development continued:

The initial trials went well but I ran out of money and went back to Fishing for 4 months.

The electronic reporting solution CEDRIC was seen as too big and powerful to replace, and the integration with it was both legally and technically tricky. The timing wasn't yet right. The Ministry were beginning to scope out a similar project - based around compliance and surveillance.

I was introduced to 2 skippers and we gained dispensation for them to use the system for real. Initial trials were a success and I was invited to Auckland to meet with AFL.

We decided to team up - and bring the two projects into one business

The business is making a difference

Now we have trials with 3 fishing companies - we are in constant contact with the Ministry and are consulting with them on their compliance project.

We are helping to shape the way fishing is assisted by technology and bringing in added value throughout the whole process.

And new opportunities and challenges emerge

We have 5 employees - and couple part time. I spend my days developing mostly and other times Business direction and strategy. We are currently attempting to enter the US.

If I was to return to study it would be communications - to be honest I really need a refresher right now!

Rimu is now acting as client for the capstone projects for six Information Technology students.

Everything is difficult - at every level it gets harder. Coping strategies fail, and have to make new ones. But determination and having the support of others makes it all possible.

At every step the Polytech has been there for support connections and ideas long after the degree was all done and finished.

Rimu's learning pathway is unique, but his approach is not. Many students come to learning with a passion or a specific goal in mind, only to have that aspiration dulled by squeezing it into a fixed curriculum.

6. INSPIRATION 2: SUSTAINABILITY MATURITY

The child's bike manufacturing company, Wishbone Design Studio is owned and managed by Rich Latham and Jan McIvor (2016). The business is values-led, entirely based on a framework of sustainability and quality. Wishbone's dream was for a product that would last

from ages one to five, and then be passed on to the next young rider. They wanted a principle of a 100% repairable product "that would never end up in the landfill" and they actively promote a second-hand market. A recent product innovation is the use of recycled carpet for the bike frame. The role of values infuses the business and the relationship with customers "because we declared our values early on – sustainability and quality – we were attracting customers of that same ilk, the pressure on us was not to drop standards, but to raise them".

On Willard's sustainability maturity model (2004), Wishbone is operating at the highest level "Sustainability-based thinking, perspectives, and behaviours are integrated into everyday operating procedures and the culture of the organization". Although anecdotal, I'm yet to find a computing organisation (research or commercial) above three on this scale: "Stage three is about incremental, continuous improvements in eco-efficiency".

It would be useful for CEfS to consider positioning itself on Willard's scale. What would computing education for sustainability look like if we did it from the same mindset as Wishbone does business? Can we imagine CEfS imaginering around strong values positions, making then breaking conventions?

7. INSPIRATION 3: WORK-BASED PROFESSIONAL PRACTICE EDUCATION

CEfS has largely been carried out within existing education pedagogy. Otago Polytechnic has adopted a heutagogical-based teaching and learning strategy that has radical impact for education. The strategy can be considered with a device recognisable to those familiar with software engineering's Agile Manifesto:

At Otago Polytechnic we have to come to value:
Processes of learning over focus on content
Lecturers as co-learners over lecturers as experts
Learner-managed learning over lecturer delivered learning
Learner-negotiated projects over lecturer defined projects
Assessment as a learning process over assessment as a summative process
Flexible learning opportunities over timetabled teaching times
That is, while we value the items on the right, we value the items on the left more.

Exemplifying this approach is the work-based learning approach of CapableNZ - the Otago Polytechnic school of professional practice. This school works with learners to recognise and extend learning in a professional work-based context at both undergraduate and post-graduate levels. At undergraduate levels CapableNZ works with learners to align their professional framework of practice - their professional identity - with graduate profiles, including the computing degree. These learners would be expected to learn new areas, mostly to wrap their practice in theoretical context, but there are no formal classes. Instead the focus is on reflection.

8. TRANSFORMATION BASED CEfS

What might these inspirations mean for CEfS? I believe that the original framing of CEfS didn't go nearly far enough.

If we look at the description of the agenda described in Mann and Smith (2007b) the preamble states:

> *"We hope that it is empowering and engaging. It is deliberately both top down and bottom up. It is deliberately both incremental and transformative. It is deliberately aimed at the champions and the "ordinary lecturer". It deliberately challenges (without pushing anything "down my throat") and provides resources to encourage".*

In retrospect, perhaps we should have challenged more. Just putting a bit of recycling and procurement into the hardware course is not enough. While we may have gotten to a point where sustainability is in many computing qualifications, perhaps this "sustainability as usual" is doing a disservice.

Maybe rather than carefully aligning sustainability with the discipline, we need to be pointing out how much change is required. If we take the example of Human Computer Interaction (HCI), seminal papers such as Blevis' Sustainable Interaction Design (2007) prompted a flurry of research in sustainable HCI. However, as Brynjarsdottir *et al.* (2012) found, much of the resultant research is weak and focusses on a limited framing of sustainability and human behaviour, or, as Meyers and Nathan (2016) bleakly described, with an "impoverished" focus. Huish's (2013) teaching of Development Activism, or "Dissent 101" might be a useful model here.

The socio-ecological restoration element of the Transformation Mindset represents an acknowledgment that humankind and the environment are inseparably intertwined. CSEfS needs to go beyond single factors such as efficiency gains, and the problem is not just about carbon or energy. How can we help reverse biodiversity loss? massive global inequities? or even local problems such as why the logs are transported on the road instead of the adjacent train track? Nor is it just about "the environment" – the systems in question are as much social as they are biophysical.

Davies (2009) argued that a learning society must be able to think systematically: focussing on "understanding the interactions between human and ecological systems, and restructuring human systems to be more sustainable". While CSEfS has the benefit of computing professionals usually being systems thinkers, we tend to be constrained in that thinking. Goldweber *et al.* (2013) point out that examples in computing text books rarely venture beyond well worked business examples. Such 'business as usual", even if it provides incremental benefits in productivity or efficiency is not going to provide transformative system change. As Robinson (2009) argued, "we need skills in effectively and persuasively presenting the proposed changes, sometimes in difficult circumstances if the change goes against the ingrained culture of the organisation".

Dam-Mieras (2006) referred to a "fragmented reality" - a sustainable mindset must cross disciplinary boundaries. CSEfS needs to teach students to adopt a holistic perspective that means working across disciplines – but to do so with humility. We need to heed Kentaro Toyama's warning in "geek heresy", that we think that throwing technology at a problem is going to solve it, but Toyama's summary is that technology exemplifies underlying human forces. If we are continuing to consume and that's the primary human force then throwing technology at it is not going to solve that problem.

The challenges of the homogeneity of the computing profession are well recognised (Bardzell, 2010, Ahmed *et al.* 2016). This needs addressing, and not just for CSEfS.

CSEfS is an activist agenda and we need to own that. Widener (2014) described the "hyphenated activist…the professor-activist, the lawyer-activist, the farmer-activist, the grandparent-activist, the student-activist. A lot of people are doing both, and they're doing both because these problems are coming closer to where they live, work, study and play. At that point, when you take a position on something, you have a multiple presence – you are what you are and you're an activist, or advocate. Not against, but advocating for. For communities, for environment, advocates for – not against". Scott's "Work Ready plus" initiative (flipcurric.org) aims to produce graduates who possess a range of work capabilities and "plus", where the plus includes being sustainability literate and "being clear on where one stands on the tacit assumptions driving the 21st century agenda, assumptions like: growth is good; consumption is happiness; ICT is always the answer; globalisation is great" (Scott 2016).

Aimers and Walker (2016) argue that we need to move beyond a selfish individualistic approach to one of empathy and valuing social capital. Knowles' *et al.* (2013) brings this values approach to computing and describes how the rational, economic man approach appealing to people's wallet is actually disabling the altruistic "we need to be doing this because it's what we need to be doing justification". As an example of this critical questioning, Knowles argued that work to develop computing for sustainability has been hampered by an ecological modernisation agenda – the optimistic thought that greening IT will save the world - "computing seeks sustainability wins that can be found within the dominant ideology of our technological era" but rarely goes beyond "encouraging unfettered consumerism and shallow forms of socialisation" . Knowles would rather a radical agenda that explores alternatives to "an inherently unsustainable digital economy, or challenging the instrumentalisation of the sustainability problem". She concludes that computing has "unwittingly narrowed its solution space", and that even greater opportunities for research might be discovered by going beyond the traditional energy efficiency focussed persuasive technology "to embrace more contemporary, more holistic, and more radical understandings of sustainability".

The nature of unsustainability means that by definition the problems aren't amenable to the experimental/intervention paradigm that computer science (and hence CSEfS) generally works under. Morris and Martin (2009) suggests that the answer may lie in the difference between a difficulty and a mess. Difficulties are problems which usually have a well-defined and clear boundary, involving few participants, short timescales and clear priorities, with limited wider implications. Messes are typified by more human-oriented issues where values, beliefs, power structures and habit play a major part. There is no well-defined problem or solution, timescales may be long and at best we can only seek to improve the situation as seen by the wide range of people involved. This is not simply a repositioning for CSEfS, it is a different way of working. By empowering individuals and groups, and ensuring that they are engaged (eg Ferrario *et al.* 2014), any actions that are taken are likely to be more successful than if 'outside experts' impose solutions. Working *with* rather than *about* or *on* is vital.

I believe that it is important that CSEfS be positive. Schendler (2009) makes an important distinction. He says it is vital that we do not see the challenge as the end of the world. Instead we can see "an opportunity on the scale of the Enlightenment or the Renaissance, a rare chance to radically change the face of society forever". Senge (2006) similarly described the problem, concluding that while we might make the planet uninhabitable, "humanity has the potential to effect a post-industrial renaissance of unimaginable beauty and value. It is the best and worst of futures that face us". This is not to deny the problem, and I recognise the urgency of directions such as collapse informatics (Tomlinson 2012). Rather, I would argue for demonstrating positive alternatives: Transition Towns or co-housing initiatives for example. Scott (2016) argues that the problem with the green movement is that "they assume, falsely, that change is achieved by brute logic. Change is not achieved by brute logic. It's achieved by, in fact, listen, link, leverage and lead" in other words, by leading positive change.

Orr (1992) described the role of an ecologically literate population. Such people, he argued are "able to distinguish health from its opposite and to live accordingly". A mission of education is to "will equip a person to live well in a place". But we should never be fooled into thinking we know it all, Vitek and Jackson (2008) asked "since we're billions of times more ignorant than knowledgeable, why not go with our long suit and have an ignorance-based worldview. They argued that a deterministic "knowledge-based worldview is both flawed and dangerous". Robert Root-Bernstein (2008) argues that science is not a

search for solutions but a search for answerable questions – it must become acceptable to say "I don't know". He challenged educators to train student to raise answerable questions that no one has ever asked - and we're not going to achieve that by always getting them to answer questions to which we already have answers.

9. CONCLUSION

On the basis that sustainability problems are not amenable to single-point interventions (because they are both wicked and numerous), we need a step-change in how we approach computing for sustainability. Rather than trying for separate interventions for every aspect, or for passive awareness, focus needs to be placed upon engaging people to affect worldviews. This deeper engagement might be through community conversations, through reflection and action research. Some computing researchers are beginning to recognise this as the next step (Silberman *et al.* 2014). Batya Friedman's (2016) multi-lifespan information systems have really looked at how we might start to address intergenerational equity. Some are working on community engagement, not as a means for behaviour change, but for the sake of an empowered community: Steve Benford's trajectories and uncomfortable interactions (Benford 2013), University of Lancaster's work on Tiree (Ferrario *et al.* 2014), Rob Comber's empowering communities (Comber 2016) and David Green's participatory documentary making (Green 2016). These research directions are supporting communities to create sustainable futures beyond a behaviour-change-intervention-via-new-product paradigm.

In order to contribute to this engagement focussed computing for sustainability, education also has to change. Bennett (2008) describes "anupholesteraphobia: the fear of not being able to cover the material" where the solution is not to try and cram more material into an already crowded curriculum, but rather to see sustainability as the context, a basis for deeper learning, or even a reason for learning.

Instead of formally teaching computing (or any other discipline for that matter), Education for Sustainability could focus on professional development and work practice - where that work is explicitly sustainability. Could we market a "Bachelor of Making a Difference" where learners are supported to undertake major projects - such as Rimu's fisheries logistics development? Learning of technical content would be on-demand as needed for the project. In Rimu's case, that on-demand learning would have included a lot of computer science, but also business management, policy development and marketing. It wouldn't be a Computer Science degree, but it would have been better in supporting his aspiration and career – and making a real difference for a sustainable future.

Computing does need to address its own footprint and it needs to educate people to do this. And it does need to maximise its handprint, and again we need to educate people to do this. But so far we have been very poor at the handprint, and even in the footprint have gotten largely stuck on energy efficiency, with limited effectiveness and quite possibly doing sustainability a disservice through misaligned values (Knowles *et al.* 2013, Knowles *et al.* 2014).

Beyond climate change, it is not hard to trace the footprint of impacts of computing on environmental degradation and social justice - as an example, to follow the pathways from our mobile devices to the inhumane conditions of the so-called "artisan" cobalt miners of the Congo.

On the handprint side, computing for sustainability cannot be just about efficiency gains, and the problem is not just about carbon or energy. How can computing help reverse biodiversity loss? Or massive global inequities? Nor is it just about "the environment" – the systems in question are as much social as they are biophysical. As a society we have to learn to live in a complex world of interdependent systems with high uncertainties and multiple legitimate interests. These complex and evolving systems require a new way of thinking about risk, uncertainty, ambiguity and ignorance (Stagl 2007). These systems require that we can think simultaneously of the drivers and impacts of our actions across scales and barriers of space, time, culture, species and disciplinary boundaries. It means that we need to switch from a focus on outcomes to one of process. Ethics and sustainability can often be described as wicked problems - rarely as simple as choosing between an obvious good and an obvious bad. We need to be thinking about every decision, every action contributing to a system operating under ethical principles. Sustainability provides a framework for expanding ethical reasoning to a complex world.

This work has been prompted by the author's increasing unease with the ability of CEfS to deliver a professional workforce committed and capable of the leverage that computing has promised in sustainability. This paper has argued that we need to step outside our comfort zone and engage in an activist approach to computing education. Previous attempts to demonstrate how sustainability fits into a computing education paradigm have not resulted in the required contribution at scale to system change actions resulting in restorative socio-ecological transformation. An alternative model is presented, which while not exhaustive, is intended to provoke debate about the nature of computing education for sustainability.

REFERENCES

Ahmed, S. I., Ahmed, N., Hussain, F., & Kumar, N. (2016). *Computing beyond gender-imposed limits*. Paper presented at the Proceedings of the Second Workshop on Computing within Limits, Irvine, California.

Aimers, J., & Walker, P. (2016). Community Development In Aotearoa New Zealand: A Historical Journey. *Whanake: The Pacific Journal of Community Development, 2*(2).

AtKisson, A. (2008). *The ISIS agreement: how sustainability can improve organizational performance and transform the world*. London: Earthscan.

Bardzell, S. (2010). *Feminist HCI: taking stock and outlining an agenda for design*. Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Atlanta, Georgia, USA.

Benford, S. and S. Mann (2013). *Experiencing changing trajectories. Sustainable Lens: Resilience on Radio.* Dunedin, NZ. [Retrieved from http://sustainablelens.org/?p=505]

Bennett, D. E. (2008). *Understanding the Classical Music Profession: The Past, the Present and Strategies for the Future*: Ashgate.

Blevis, E. (2007). *Sustainable Interaction Design: Invention and disposal, renewal and reuse*, San Jose, California.

Brynjarsdottir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., & Sengers, P. (2012). *Sustainably unpersuaded: how persuasion narrows our vision of sustainability*. Paper presented at the Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems, Austin, Texas, USA.

Comber, R. and S. Mann (2015). Empowering communities. Sustainable Lens: Resilience on Radio. Dunedin, NZ [Retrieved from http://sustainablelens.org/?p=1000]

Daly, H. E. (1996). *Beyond Growth: The Economics of Sustainable Development*. Boston: Beacon Press.

Dam-Mieras, R. *v.* (2006). Learning for Sustainable Development: Is it Possible Within the Established Higher Education Structures? In J. Holmberg & B. E. Samuelsson (Eds.), *Drivers and Barriers for Implementing Sustainable Development in Higher Education* (pp. 13-18). Paris: UNESCO Edcuation.

Fagan, G. (2009). The Emerging Paradigm. In A. Stibbe (Ed.), *The Handbook of Sustainability Literacy: Skills for a Changing World* (pp. online). Foxhole, Dartington, Totnes: Green Books.

Ferrario, M. A., Simm, W., Newman, P., Forshaw, S., & Whittle, J. (2014). *Software engineering for 'social good': integrating action research, participatory design, and agile development*. Paper presented at the Companion Proceedings of the 36th International Conference on Software Engineering, Hyderabad, India.

Friedman, B. and S. Mann (2016). Values: working on problems that really matter. Sustainable Lens: Resilience on Radio. Dunedin, NZ. [Retrieved from http://sustainablelens.org/?p=1022]

Goldweber, M., Barr, J., Clear, T., Davoli, R., Mann, S., Patitsas, E., & Portnoff, S. (2013). A framework for enhancing the social good in computing education: a values approach. *ACM Inroads, 4*(1), 58-79. doi:10.1145/2432596.2432616

Green, D. and S. Mann (2015). Participatory documentary storytelling. Sustainable Lens: Resilience on Radio. Dunedin,NZ. [Retrieved from http://sustainablelens.org/?p=998]

Huish, R. (2013). Dissent 101: teaching the "dangerous knowledge" of practices of activism. *Canadian Journal of Development Studies / Revue canadienne d'études du développement, 34*(3), 364-383. doi:10.1080/02255189.2013.809334

Knowles, B., Blair, L., Coulton, P., & Lochrie, M. (2014). *Rethinking plan A for sustainable HCI*. Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Toronto, Ontario, Canada.

Knowles, B., Blair, L., Hazas, M., & Walker, S. (2013). *Exploring sustainability research in computing: where we are and where we go next*. Paper presented at the Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing, Zurich, Switzerland.

Krumdiek, S. Mann, S. (2015). *Transition Engineering* [Retrieved from http://sustainablelens.org/?p=859

Laitner, S., Gallagher, S., Mann, S. (2014). Intelligent efficiency. Sustainable Lens: Resilence on Radio. Dunedin, NZ.[Retrieved from http://sustainablelens.org/?p=636]

Latham, R, McIvor, J., Mann, S. (2016). *Value driven bikes* [Retrieved from http://sustainablelens.org/?p=992]

Mann, S. (2011). *The Green Graduate: Educating Every Student as a Sustainable Practitioner*. Wellington: NZCER Press.

Mann, S., Eden-Mann, P., Smith, L., Ker, G., Osborne, P. &Alexander-Crawford, P. (2017). A transformation mindset as the basis for sustainable community development. International Conference of the Association of Community Development, Auckland.

Mann, S., & Ellwood, K. (Eds.). (2009). *A Simple Pledge. Towards Sustainable Practice*: Otago Polytechnic.

Mann, S., Muller, L., Davis, J., Roda, C., & Young, A. (2009). Computing and sustainability: evaluating resources for educators. *ACM SIGCSE Bulletin, 41*(4), 144-155. doi:http://doi.acm.org/10.1145/1709424.1709459

Mann, S., & Smith, L. (2007a, 7th-10th July). *Computing and sustainability.* Paper presented at the 20th Annual Conference of the National Advisory Committee on Computing Qualifications, Nelson, New Zealand.

Mann, S., & Smith, L. (2007b, 7th-10th July 2006). *Computing Education for Sustainability*. Paper presented at the 20th Annual Conference of the National Advisory Committee on Computing Qualifications, Nelson, New Zealand.

Mann, S., Smith, L., & Muller, L. (2008). Computing education for sustainability. *SIGCSE Bull.*, *40*(4), 183-193. doi:http://doi.acm.org/10.1145/1473195.1473241

Meyers, E. M., & Nathan, L. P. (2016). *Impoverished Visions of Sustainability: Encouraging Disruption in Digital Learning Environments*. Paper presented at the Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing, San Francisco, California, USA.

Olsson, P., Folke, C., & Hahn, T. (2004). Social-Ecological Transformation for Ecosystem Management: the Development of Adaptive Co-management of a Wetland Landscape in Southern Sweden. Ecology and Society, 9(4). doi:10.5751/ES-00683-090402

Orr, D. W. (1992). *Ecological Literacy: Education and the Transition to a Postmodern World.* Albany: State University of New York Press.

Parker, J., Wade, R., & Atkinson, H. (2004). Citizenship and Community from Local to Global: Implications for Higher Education of a Global Citizenship Approach. In J. Blewitt & C. Cullingford (Eds.), *The Sustainability Curriculum: The Challenge for Higher Education* (pp. 63-77). London: Earthscan.

Placet, M., Anderson, R., & Fowler, K. M. (2005). Strategies for Sustainability. *Research Technology Management*, *48*(5), 32-41

Preist, C. and S. Mann (2013). Environmental impact of digital transformation. Sustainable_Lens_-Resilience_on_Radio. S. Mann and S. Gallagher. [Retrieved from http://sustainablelens.org/?p=473]

Raghaven, B., Mann, S. (2016). Computing at the heart of culture change. Sustainable Lens: Resilience on Radio. Dunedin, NZ. [Retrieved from http://sustainablelens.org/?p=980]

Read, A., and Mann, S. (2014). *Whale of wicked problems* [Retrieved from http://sustainablelens.org/?p=590]

Root-Bernstein, R. (2008). I Don't Know! In W. Vitek & W. Jackson (Eds.), *The virtues of ignorance: complexity, sustainability, and the limits of knowledge* (pp. 233-250). Lexington: University Press of Kentucky.

Robinson, Z. (2009). Greening Business: the ability to drive environmental and sustainability improvements in the workplace. In A. Stibbe (Ed.), *The Handbook of Sustainability Literacy: Skills for a Changing World* (pp. 130-136). Totnes, Devon: Green Books.

Schendler, A. (2009). *Getting Green Done: Hard Truths from the Front Lines of the Sustainability Revolution*. New York: Public Affairs.

Scott, G., & Mann, S. (Producer). (2016). Educating for professional dilemmas *Sustainable Lens: Resilience on Radio*. Retrieved from http://sustainablelens.org/?p=1111

Senge, P. M., Smith, B., Schley, S., Laur, J., & Kruschwitz, N. (2008). *The Necessary Revolution: How individuals and organizations are working together to create a sustainable world.*: Doubleday Publishing.

Silberman, M. S., Nathan, L., Knowles, B., Bendor, R., Clear, A., H, M., . . . Mankoff, J. (2014). Next steps for sustainable HCI. *interactions*, *21*(5), 66-69. doi:10.1145/2651820

Stagl, S. (2007). Theoretical foundations of learning processes for sustainable development. *International Journal of Sustainable Development and World Ecology*, *14*(1), 52-62.

Sterling, S. (2004). An Analysis of the Development of Sustainability Education Internationally: Evolution, Interpretation and Transformative Potential. In J. Blewitt & C. Cullingford (Eds.), *The Sustainability Curriculum: The Challenge for Higher Education* (pp. 43-62). London: Earthscan.

Sterling, S. (2009). Ecological intelligence: viewing the world relationally. In A. Stibbe (Ed.), *The Handbook of Sustainability Literacy: Skills for a Changing World* (pp. 77-83). Foxhole, Dartington, Totnes: Green Books.

Svanström, M., Lozano-García, F. J., & Rowe, D. (2008). Learning outcomes for sustainable development in higher education. *International Journal of Sustainability in Higher Education, 9*(3), 339-351.

Tipene, P., Mann, S. (2016). *Rejoicing in who we are* [Retrieved from http://sustainablelens.org/?p=1116]

Thøgersen, J., & Crompton, T. (2009). Simple and Painless? The Limitations of Spillover in Environmental Campaigning. *Journal of Consumer Policy, 32*(2), 141-163. doi:10.1007/s10603-009-9101-1

Tomlinson, B., Silberman, M. S., Patterson, D., Pan, Y., & Blevis, E. (2012). *Collapse informatics: augmenting the sustainability & ICT4D discourse in HCI*. Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Austin, Texas, USA.

Toyama, K., & Mann, S. (Producer). (2016). Technology amplifies underlying human forces. Retrieved from http://sustainablelens.org/?p=933

Vitek, B., & Jackson, W. (2008). *The virtues of ignorance: complexity, sustainability, and the limits of knowledge*. Lexington: University Press of Kentucky.

Willard, B. (2005). *The Next Sustainability Wave: Building Boardroom Buy-in (Conscientious Commerce)*. Gabriola Island, British Columbia, Canada: New Society Publishers.