Enhancing ESD Through the Master of Clean Energy Engineering Co-op Program: A Canadian Case-Study

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Abstract

Like many other universities worldwide, the University of British Columbia in Canada promotes teaching and research on sustainability and has a history of pursuing strong operational sustainability goals. UBC demonstrates innovation by going a step further to integrate efforts with the help of its University Sustainability Initiative (USI). By fostering partnerships and collaborations that extend beyond traditional disciplinary boundaries, the initiative intersects two important themes: using the campus as a living laboratory and empowering students as agents of change. In addition to 480 sustainability-related courses, UBC has 41 sustainability-related programs. Our paper will describe one of them —the Master of Engineering in Clean Energy Engineering with a co-op option, offered by the Faculty of Applied Science and the Clean Energy Research Centre. This program is the only one of its kind in Canada. It provides advanced training in energy efficiency and conservation, including technologies that will help to meet the global need for energy while reducing electricity consumption, as well as greenhouse gases and other emissions. The co-op option provides a deeper and richer form of learning by presenting an authentic learning space and adding a significant value to education for sustainable development. Students complete co-op work terms within various industry sectors including consulting, municipal government, and in the pulp and paper industry, in positions focused on demand-side energy efficiency and conservation work. The paper describes the Engineering Co-op Program and two significant partnerships with the BC Hydro

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Power Smart Initiative and FortisBC, electricity and natural gas corporations in British Columbia, Canada, that support the program by providing expertise and co-funding of co-op work terms. Knowledge of this successful initiative could be valuable for many universities that are engaged in promoting university-industry partnerships within the global engineering curriculum.

Keywords
Clean energy engineering · Energy efficiency and conservation · Transformative learning · Co-operative education · Industry partnership

1 Introduction

In the years since the Bruntl and Report, sustainability has become a global priority (Anderberg et al. 2009; Barth et al. 2007; Leal Filho 2009), and the global community engaged in developing strategies to fight climate change, poverty and environmental degradation (Cebrián et al. 2012). The Declaration of the United Nations Decade of Education for Sustainable Development (abbr. DESD 2005–2014) brought forth a socio-political understanding that nothing less than a paradigm shift was on the agenda—an epistemological change towards sustainability. A consensus was reached that "it is imperative that society transforms its relationship with the use of resources" (Desha and Hargroves 2012, p. 29). Sustainability "implies a change of fundamental epistemology in our culture" and, consequently, in our education, research and practice (Sterling 2004). Instead of simply reproducing the existing social structure, a paradigm shift enables social transformation for a better, more sustainable world. Education for sustainable development (ESD), therefore, includes education for a sustainable social transformation (Cebrián et al. 2012). Such a social transformation stimulates critical reflection, clarification and reassessment of values (Tappeser and Meyer 2012, p. 395).

ESD plays a key role in fostering "a more sustainable, equitable and socially just society" (UNESCO 2005). Universities around the globe are engaged in "transforming students to become future leaders, empowered and motivated to make decisions for sustainability" (Anderberg et al. 2009; Barth et al. 2007; Shriberg 2012). Many universities in North America made a conscious effort to promote education and research for SD and to pursue strong operational sustainability goals. In Canada, the University of British Columbia, a Tier One research university, started a curriculum and organizational change using a "whole-system" approach described in the literature (see, for example, Desha and Hargroves 2012).

This paper describes the journey undertaken by the University of British Columbia (UBC) in order to encourage education and research for SD, to offer a transformative learning experience, and to develop learning communities for sustainability. The authors present the milestones reached along this path and discuss significant initiatives, among them "UBC as a living lab" and "UBC as an agent of change". The authors further introduce one of UBC's 41 sustainability-related

programs– the Master of Engineering in Clean Energy Engineering degree program, focusing on its co-operative education option, offered by the Engineering Co-op Program at the Faculty of Applied Science. Because engineering students will be required to play a leading role in the enactment of sustainable development, they should learn how to deliver solutions that are not only technically and commercially viable, but also environmentally and socially sustainable. In order to develop appropriate competencies and skills, partnerships between the university and industry are instrumental. The authors discuss the role of industry partnerships in the development of the co-operative education option and the resulting change in the students' and employers' appreciation of core competencies and skills.

2 Theoretical Framework and Methodology

Due to the need for a paradigm change, the universities around the globe were required to transform yet again, thanks to the new understanding of sustainability, pedagogy and methodology. The University of British Columbia included in its Strategic Plan the goal to provide every student the opportunity for transformative student learning through outstanding teaching and research, enriched educational experiences, and rewarding student life (Place and Promise 2014). Learning takes place "within the social and emotional context of each student's life" (Place and Promise 2014). Applying new pedagogical research, UBC is expanding learning opportunities outside of the classroom, e.g., through community service learning, international opportunities, internship and mentorship, experiential learning and co-op experiences (Place and Promise 2014).

Transformative learning is "the capacity to change existing patterns and worldviews, to construct new knowledge collectively, to challenge and improve practice, and to critique and examine sustainability issues" (Sterling 2004). Transformative learning theory (Mezirow 2009) is particularly useful for this study because it emphasises critical reflection, dialogue and holistic learning. In particular, transformative learning theory and action research are instrumental for examining the value of experiential learning and its impact on the change of students' understanding of core competencies and skills.

Action research is a useful method for our study that can be combined with observation, interviewing, and pedagogical reflection. It is also important in projects involving industry partners because it can contribute to the transformation of professional practice and generate new knowledge (Cohen et al. 2000; Cebrián et al. 2012; Somekh 2006). Action research promotes emancipatory rather than technical change, so it is can help faculty and staff to embed ESD in the curriculum. It can be undertaken by a group of instructors working at the same university, researchers within the same institution, students and advisers (Cebrián et al. 2012; Somekh 2006). Our research team, comprised of faculty and staff members, chose emancipatory action research (EAR) due to its potential to engage participants in a learn-by-doing process accompanied by critical reflection, clarification of essential values, and exploration of contrasting viewpoints (Cohen et al. 2000; Somekh 2006).

Transformative learning theory and EAR were used to develop flexible learner-centered pedagogy for the needs of co-operative education. Data about students' and employers' evaluation of competencies and skills were collected through surveys, focus group discussions, observation, and analysis of institutional and program resources.

3 UBC's Sustainability Milestones

In 1990 the University of British Columbia signed the Talloires Declaration and started an important transformation of its ethos. ESD became an agenda of growing significance that resulted in changes in curriculum, pedagogy, structure, and organization. Bridging the gap between knowledge and action, UBC became the first university in Canada to adopt a sustainable development policy and to open a campus sustainability office. UBC Strategic Plan, *Place and Promise*, contains nine commitments with goals and actions designed to realize the university's vision for the future. Sustainability is a key commitment, recognizing that, "in order to meet society's needs without compromising those of future generations, the best efforts of the brightest minds are required" (Place and Promise 2014).

The University has marked its progress with numerous milestones summarized in Table 1. Its Vancouver campus has been transformed into a vibrant, sustainable community where students, faculty, staff and local residents live, work and learn. In response to the challenge of creating a more sustainable society, in 2011 UBC opened the Centre for Interactive Research on Sustainability (CIRS). CIRS has become an internationally recognized research facility that accelerates the adoption of sustainable building technologies and sustainable urban development practices (UBC Sustainability 2014).

4 UBC as a Living Lab and an Agent of Change

The University Sustainability Initiative (USI) was established in 2010 to integrate academic and operational sustainability efforts and to act as the University's agent in ESD innovation. It fosters partnerships and collaborations that extend beyond traditional boundaries of disciplines and sectors and works in two related areas: establishing the campus as a living laboratory and transforming the whole University as an agent of change (UBC Sustainability Initiative 2014).

As Shriberg (2012) notes, "leading institutions of higher education are increasingly utilizing the campus as a laboratory to move beyond organizational "greening" into developing the skills set in students to lead deep institutional changes for sustainability in academia and beyond" (p. 19). The entire UBC campus is regarded as a living laboratory, as a "teaching tool" (Savanick Hansen and Wells 2012), providing the community with the freedom to explore the technological, environmental, economic and social aspects of sustainability. The four parts of the "living laboratory" initiative are:

Table 1 UBC sustainability milestones

Period	Initiative
1990–2000	1990—UBC signs the international talloires declaration
	1996—Faculty members of UBC's School of Community and Regional Planning originate the award-winning ecological footprint concept
	1997—UBC is Canada's first university to adopt a sustainable development policy
	1998—UBC is Canada's first university to open a campus sustainability office
2001–2005	2001—UBC launches EcoTrek (2001–2008), the largest energy and water retrofit at a Canadian campus at the time
	2003—UBC pioneers the U-Pass program
2006–2010	2006—UBC publishes *Canada's first campus-wide sustainability strategy*
	2007—UBC reaches its kyoto targets, reducing GHG emissions from academic buildings to six per cent below 1990 levels; faculty member Dr. John Robinson shares the 2007 Nobel Prize with former US Vice President Al Gore as a member of the intergovernmental panel on climate change
	2008—UBC is the first to sign the *climate change statement of action for canada* and *achieves an A-rating in the sustainable endowment institute's green report card*, among the top in North America
	2009—UBC develops the Sustainability Academic Strategy, which recommended establishing and expanding shared infrastructure and programs to connect sustainability across academics and operations; UBC integrates sustainability as one of nine core commitments in "Place and Promise", further institutionalizing sustainability in UBC's highest-level strategic plan; UBC publishes a series of case studies on sustainability
	2010—UBC commits to reducing GHG emissions 33 % by 2015, 67 % by 2020, and 100 % by 2050, compared to 2007 levels; UBC launches the Sustainability Initiative (USI) that promotes and unites sustainability efforts in teaching and learning, research and campus operations
2011–2012	2011—UBC opens the *Centre for Interactive research on sustainability (CIRS)*, the most innovative and high performing building in North America; UBC's Vancouver campus is designated *Canada's first Fair Trade campus* by FairTrade Canada;
	UBC breaks ground on one of the largest *steam-to-hot water conversion projects* in North America, which will reduce GHG emissions by 22 %;
	UBC receives *Canada's first gold rating in STARS* (*Sustainability Tracking, Assessment and Rating System*), a comprehensive university sustainability rating system
	2012—UBC opens the *bioenergy research and demonstration facility* which will reduce campus GHG emissions by 9 % and introduce clean energy technologies at a community scale

Source Our Story (2014)

1. The integration of UBC's core academic mandate (research and teaching) with the University's operations.
2. Partnerships between the University and private sector, public sector or NGO organizations.

3. Sound financial use of UBC's resources and infrastructure.
4. The potential to transfer the knowledge UBC gains into practical, positive action applicable to the greater community.

UBC is uniquely suited to act as a living laboratory, as a community of over 49,000 students, 13,000 faculty and staff, and residents, with over 50 % of campus households occupied by someone who studies or works at UBC. The university has about 500 buildings covering 402 hectares of land, owns and operates its own utilities including electrical, heating, water and waste, and is responsible for its roads and infrastructure (UBC Sustainability Initiative 2014).

UBC is representative of many communities; therefore, many communities can implement sustainability solutions developed here. For example, while transforming the campus into a completely sustainable community, UBC researchers are studying new approaches to UBC's energy generation and distribution systems (UBC Sustainability Initiative 2014).

As an agent of change, the University is training the future "green leaders" who will take ESD principles beyond the gates of campus and effect positive change. As noted by Shriberg (2012), "leadership skills and practices to guide society on a sustainable path are and will continue to be in high demand" (p. 19). UBC scholars and students conduct important research, while the University's private, public and NGO partners contribute expertise, human capital and resources to projects that might not otherwise be available. Private sector partners help to commercialize and take to market technologies and innovations developed on campus; public sector partners help to develop policies and regulations and share them with other communities; NGO partners help with social licence and community engagement efforts.

To support students in reaching their potential, UBC has established sustainability "pathways" that allow students, regardless of their disciplines, to integrate sustainability into their studies. UBC offers more than 480 sustainability courses and 41 programs that range in scope from the highly specialized to the multidisciplinary. A number of non-credit options are also available, such as UBC Reads Sustainability events with authors, volunteer opportunities at the UBC Farm, participation in the SEEDS Program, etc. (UBC Sustainability Initiative 2014).

5 UBC's Master's Program in Clean Energy Engineering

One of the University's important initiatives is the graduate program "Master of Engineering in Clean Energy Engineering" offered through the UBC Clean Energy Research Centre[1] in the Faculty of Applied Science. This is the only program of its kind in Canada and one of only a handful in the world. This program enables the University to stay at the forefront by providing advanced training in energy

[1] The UBC Clean Energy Research Centre (CERC) is "dedicated to developing knowledge and solutions aimed at reducing the environmental impact of energy consumption and ensuring the sustainability of our energy supply" (CERC 2013, 2014a, b, c).

Table 2 Scheduling of the master of engineering in clean energy engineering co-op program

Academic calendar	Fall (Sept–Dec)	Winter (Jan–April)	Summer (May–Aug)
Year 1	Study	Study	Work-term 1
Year 2	Work-term 2	Study	Graduation

The North American academic year commences in September
Source Engineering Co-op Program (2013b)

efficiency and conservation. Offered by the Faculty of Applied Science and the Clean Energy Research Centre, the program is focused on the supply-and-demand side of energy. This includes energy conservation, social change concepts, efficient use of electricity and natural gas, energy supply, and methods for comparing and evaluating alternative energy scenarios (CERC 2014c). Students study sustainable energy sources such as biomass, solar, wind and small-scale hydro, in addition to having a concentration on business, management, leadership and other aspects of energy efficiency and conservation (CERC 2014c).

This program has a co-operative education option,[2] allowing the students to complete a four- or eight-month work experience (Engineering Co-op Program 2013a). The option is facilitated through the Engineering Co-op Program, the largest co-operative engineering co-op program in Western Canada. The Engineering Co-op Program is offered at both the Vancouver and Okanagan (in the Interior region of British Columbia) campuses. The Engineering Co-op Program at the Vancouver campus commenced in 1978; since its inception, the program has secured over 22,000 co-op work term opportunities for students with employers locally, nationally and internationally. The co-op option is a non-mandatory program and available in all 11 undergraduate disciplines and Master of Engineering, Master of Software Systems (the only mandatory co-op option) and Master of Applied Science degree programs. The University of British Columbia Okanagan campus opened its doors in 2005 and has co-op options in all three undergraduate disciplines in addition to Master of Engineering degree programs.

The UBC Engineering Co-op Program combines classroom learning with relevant, technical, paid, monitored and evaluated co-op work experiences. Students participating in the Master of Engineering in Clean Energy Engineering co-op option alternate between three academic terms and one- or two- engineering co-op work terms. Table 2 represents the academic scheduling of the Master of Engineering in Clean Energy Engineering Co-op Program.

The Master of Engineering in Clean Energy Engineering, non-mandatory co-op option, that is now in its 5th year, adds a significant value to ESD by presenting an authentic learning space that provides students advanced training that will help

[2] As outlined in the UBC academic calendar, "Co-operative Education is a partnership between students, employer and the University of British Columbia. As an educational process, co-operative education formally integrates a student's academic studies with paid, approved, career-related work experience in participating employer organizations" (UBC Vancouver Academic Calendar 2014/15 2014).

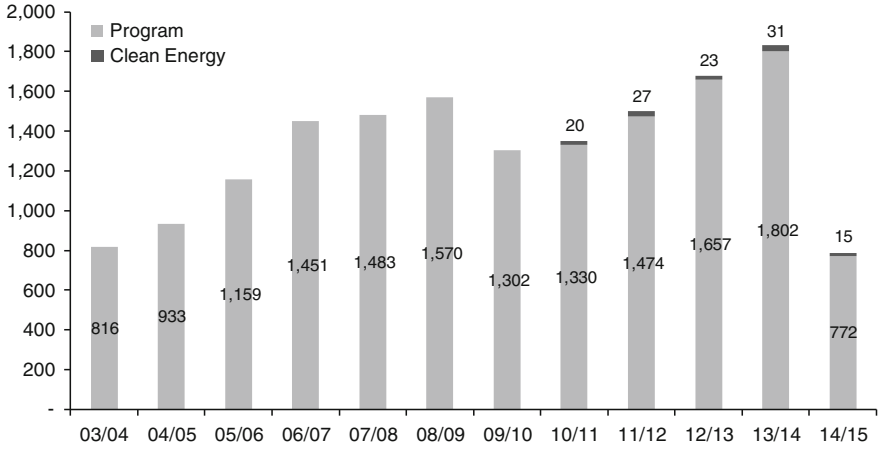

Fig. 1 Co-op Work Term Statistics for the master of engineering in clean energy program. *Source* Engineering Co-op Program (2013b)

meet the global need for energy while reducing energy consumption, greenhouse gases and other emissions. Since the inception of the program, Master of Engineering in Clean Energy Engineering co-op students have secured 116 co-op work terms. Co-op work term statistics are provided in Fig. 1.

The value of authentic learning spaces has been widely discussed in literature (Pretorius 2012). The advantages of the co-op option are significant and multiple: UBC students gain up to eight-months of paid, relevant and invaluable work experience, while businesses gain access to bright, motivated students for short-term employment. Many co-op students, in fact, return to employers with whom they have had their co-op experience for employment after graduation as energy professionals and have a significant impact on the engineering community both domestically and internationally (Engineering Co-op Program 2013a).

From the commencement of the program, there was great interest and support from BC Hydro, a provincial Crown corporation in British Columbia, Canada, that generates, purchases, distributes and sells electricity. BC Hydro was instrumental in providing the first co-op salary subsidy offered in the program, called the 'BC Hydro Power Smart Salary Subsidy for Co-op Work Terms'. The objective of BC Hydro Power Smart co-funding was to provide opportunities for students to gain experience in the application of energy efficiency, conservation skills and concepts in the commercial and industrial sectors of British Columbia (Engineering Co-op Program 2013a). More recently, another company, FortisBC (a natural gas, electricity and alternative energy retail company in British Columbia, Canada) followed with support through the 'FortisBC Salary Subsidy for Co-op Work Terms' (UBC's Master of Clean Energy 2014). In Canada BC Hydro and FortisBC are leaders in sustainable energy and in producing and delivering electricity and natural gas in environmentally and socially responsible ways. Through successful partnerships involving the UBC

Sustainability Office, the UBC Faculty of Applied Science, BC Hydro Power Smart and FortisBC, two types of co-op salary subsidies are now available. Both subsidies were solely created for provincial employers hiring Master of Clean Energy Engineering students in approved industry co-op work terms in the areas of electrical and natural gas energy efficiency and conservation (Engineering Co-op Program 2013a) and have been instrumental in the steady growth of the program.

Salary subsidy funding is provided to companies offering approved co-op industry experiences in the form of 50 % or up to $5,500 of a co-op student salary over a four-month work term. Approved industry experiences are full-time positions of 35–40 h per week for a minimum of 12 consecutive weeks to a maximum of 32 consecutive weeks (Engineering Co-op Program 2013a).

The provision of co-op salary subsidies offered through public and private partners in the Province demonstrates the University's strong support and commitment to sustainability and transformational learning. Master of Engineering in Clean Energy Engineering Co-op students that are employed by industry partners who have utilized either the BC Hydro Power Smart or FortisBC salary subsidy have worked in a number of positions. The focus of their work term has been on the application of energy efficiency and conservation skills on the demand side of the energy system in either electrical or natural gas energy savings. Students apply ESD concepts during their co-op industry work terms in one or more of the following areas (Engineering Co-op Program 2013a):

- Research and development of new, demand-side technologies that save electrical energy or natural gas energy
- Analysis, energy modelling, or design of new or existing homes, commercial buildings and industrial facility energy use
- Testing, energy studies or measurement of energy performance technologies and facilities
- Monitoring, targeting and reporting; measurement and verification methods
- Energy management or energy coaching including operation and maintenance in support of efficiency
- Energy economics, decision-making and behaviour in homes or businesses
- Policy support of energy efficiency initiatives such as building codes equipment standards and government or utility incentive programs
- Local government programs that include the efficient use of natural gas
- Conservation programs for natural gas
- Natural gas energy efficiency business case development and financial analysis.

As part of the ongoing efforts to evaluate and improve the UBC Engineering Co-op Program, during each work term students and employers are given the opportunity to complete a brief on-line survey concerning their experiences. Results are compiled per discipline annually. Numerical data supplied by students are compiled on the following topics: students' perception of job information, job quality, technical competencies and transferrable sills, job recommendations, goals and reflection, administration review, co-op coordinator review, and co-op program

review. Numerical data from employers are compiled on student technical competence and transferable skills, overall performance, and co-op program feedback. In 2012/2013 the following results were obtained from participating students and employers (Engineering Co-op Program 2013b):

- Hundred percent of students agreed that they were satisfied with the work term experience, that the work term experience was influential in developing their career and academic goals, and that their academic program had prepared them well for the work term.
- Employers ranked the students on a list of technical competencies and transferable skills that have been defined by the Canadian Engineering Accreditation Board (2012). The following competencies and skills were ranked the highest with an Excellent-Good rating: 'Knowledge Base for Engineering', 'Problem Analysis', 'Investigation', 'Teamwork', 'Individual Work', 'Professionalism', 'Impact of Engineering on Society and the Environment', 'Ethics and Equity', and 'Life-long Learning'. Ranked second was 'Use of Engineering Tools' (93.3 %), and third 'Communication Skills' (92.8 %).
- Employers judged 100 % of students to be good or outstanding in their overall work term performance.

The high percentage of stakeholder satisfaction levels demonstrates the value perceived, impact of the experience, and value of authentic learning spaces that the co-op option provides.

6 Conclusion

In 1990, along with hundreds of other leading educational institutions who signed the Talloires Declaration, the University of British Columbia pledged to make sustainability the foundation for campus operations, research and teaching (UBC Sustainability 2014). Since that time the whole university community has engaged in participatory action research in order to enable the paradigm shift towards embracing sustainability. This was undertaken by encouraging research, partnership, curriculum and organizational change. A deep integration of operational and academic efforts in sustainability challenged the UBC community to reach across traditional boundaries of disciplines and sectors. Over the years, by using the "whole-system" approach, the University has engaged its community in ESD in the following ways:

1. At the organizational level UBC has committed to a deep integration of its operational and academic efforts.
2. UBC research teams reported on the devastating consequences of unsustainable development, as well as studying people's behaviours and advancing sustainability scholarship inside and outside UBC.
3. On the curriculum level, hundreds of ESD-related courses, programs and educational events were developed for faculty, staff and students.

Importantly, UBC has established partnerships with private companies, the public sector, and NGOs. The partnerships formed with the BC Hydro Power Smart Initiative and FortisBC support the Master of Engineering in Clean Energy Engineering program by providing expertise and co-funding of co-op work terms. This training includes technologies that will help to meet the global need for energy while reducing electricity consumption, as well as greenhouse gases and other emissions. The results discussed in the paper could be valuable for many universities that are engaged in promoting university-industry partnerships within the global engineering curriculum.

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