Graduate Student Action Research to Support Development of Engineering for Sustainable Development Degree Programs, Part I: Collaborative Community Action Research Vignettes.

Cory D. Jensen^{1, 2, §}

¹College of Computer Science and Engineering, Colorado School of Mines, Golden CO, USA

²Division of Liberal Arts and International Studies, Colorado School of Mines, Golden CO, USA

[§]Present Association; Federal Energy Regulatory Commission, Washington, D.C., USA

Abbreviations

AASHE - Association for the Advancement of Sustainability in Higher Education

CASA - Cole Arts and Science Academy

CSM – Colorado School of Mines

DfE – Design for the Environment

DPS - Denver Public School

EESD – Engineering Education for Sustainable Development

EIC – Environment as an Integrated Context

EPS - Engineering Problem Solving

HEI – Higher Education Institution

HESD – Higher Education for Sustainable Development

HVAC – Heating Venting Air Conditioning

LCA - Life Cycle Assessment

LCC - Life Cycle Cost Assessment

LCSA - Life Cycle Sustainability Assessment

PERW - Participatory Emergent Readers and Writers

S⁴ – STEM Sustainability Science Station

SLCA - Social Life Cycle Analysis

STEM – Science Technology Engineering Mathematics

STEAM - Science Technology Engineering Arts and Mathematics

UNESCO - United Nations Educational, Scientific and Cultural Organization

US EPA – United States Environmental Protection Agency

Abstract

This research aids in filling a gap to provide for action research from a bottom-up approach (i.e. student, not faculty initiated) that provides for desired outcomes in support of more rigorous education development that links traditional science technology engineering and mathematics (STEM) to community, incorporates social science and arts topics (therefore creating STEAM) and frames challenges for continued programmatic promotion. Two vignettes from multiple years of field research demonstrate boundary work that could be used to initiate larger discussions, and serves as a real example for graduates students wishing to promote degree programs with sustainability themes.

1 Introduction

Imagine a picture of a child cooking bread over a pile of smoldering cow dung in an enclosed room. Scientists have shown that the use of solid fuels in enclosed spaces are a less than desirable means of food preparation due to increases in respiratory illness, pulmonary diseases, and premature death (Brunekreef & Holgate 2002, Pope et al. 2010, Perez-Padilla et al. 2010). Alternatively, imagine the distress that arises if you had to spend several hours a day to provide water for your family (Koolwal & Van de Walle 2013). What other life activities might you have to forgo and have you ever imagined that gender could have an implication on your interaction with provisioning for what many would consider a common good (Ray 2007)? Finally, what if you couldn't pay all of your bills on time? How do think would you respond, how would you manage your life, what could you possibly resort to make ends meet?

These images present complex situations, applicable to global *North* and *South* populations. In some cases, simply applying developed world solutions is not possible and has been cited as potentially detrimental (Schillhorn van Veen, 2005). The initial example is a reality for half of the world's population and near unity of the rural poor (Bruce et al. 2006). Yet, how easily could these situations arise that would require resilience? Further, do we not empathize with them, if so, why not? Clearly, rising global population will continue to place pressure on global society and earth systems to provide for materials, human needs, and equity as development surges on. Thought leaders cite: energy security (Yergin 2006), food systems (Godfray et al. 2010), water supply-quality (Oki and Kanae 2006), education (Davidson et al. 2009), justice (Nagel 2005), gender issues (Moser 2006), health care (Gardner et al. 2007, Hotez 2008) and the prevention of environmental degradation (Goodland 1995) as themes of concern to be addressed in order to preserve lasting social harmony.

The growth of a job market (Davies 2011, NAS 2013) has caused several schools to analyze education possibilities and suggest applied educational preparation (Jensen 2015).

Academically, progress toward degree programs is reported to lag behind practice (e.g. Lozano et al. 2013A, Lozano et al. 2014B, and Manring 2014). Attempts to address gaps lacks in the creation of a “rigorous conceptual framework” (Karatzoglou 2013) and has entailed research of a “descriptive nature which can be inspiring and encouraging for future peer efforts but of limited added value to theory development” (Karatzoglou 2013).

This research aids in filling a gap to provide for action research from a bottom-up approach (i.e. student, not faculty initiated) that provides for desired outcomes in support of more rigorous education development that links traditional science technology engineering and mathematics (STEM) to community, incorporates social science and arts topics (therefore creating STEAM) and frames challenges for continued programmatic promotion. It is proposed that the continued strengthening of life-long educational practices that promote concepts of sustainable development (Cortese 2003), values, and social resilience in engineering practice by creating holistic cultures of practice (Moore 2005) that can contribute to lasting solutions. A need for additional bottoms up research and degree programs is evident (Yuan and Zuo 2013). This type of research, post the United Nations Decade on Education for Sustainable Development (2005-2014), is inline with the subsequent United Nations Education Scientific and Cultural Organization’s (UNESCO) Global Action Programme (GAP) to operationalize outcomes in a two fold approach uniting education and sustainable development in collaborative action. This paper describes two vignettes of action among many, cast from a graduate student’s perspective and ability to implement, operationalize, and suggest that the UNESCO GAP could be a reality.

A definition for an engineer masterful in the application of sustainable development could be characterized by quoting a portion of the Barcelona Declaration (2004):

“It is undeniable that the world and its cultures need a different kind of engineer, one who has a long-term, systemic approach to decision-making, one who is guided by ethics, justice, equality and solidarity, and has a holistic understanding that goes beyond his or her own field of specialization”.

To manage change in sustainability practices, an International Society of Sustainability Professionals survey states leaders must be change agents, ethical, decisive, confident, proactive, critical thinkers, versatile, process focused, open-minded and accountable (Willard et al. 2014, Willard et al. 2010). These are powerful concepts that are also called upon by Lozano et al. (2013A & B) to make ESD a ‘Golden-thread’ in the academic setting.

2 Context and Theory of Sustainability Education

Sustainability education requires holistic perspectives and is cited as a critical component in providing solutions for complex problems in this, the age of the Anthropocene (Kates et al. 2001, Clark and Dickson 2003). Many engineering disciplines have proposed incorporating sustainability by subtly adopting relevant themes into typical classroom lessons or modules. However, a more comprehensive approach is necessary to create sustainability-focused curriculum, i.e. extra-classroom settings, integration among the many levels of education, intercultural-multidisciplinary skills, and environmental literacy (Martins et al. 2006, Fenner et al. 2006). Clearly these topics stretch beyond superficially fulfilling an education standard in a classroom and require rich, contextual experiences as suggested by the UNESCO GAP. Peer and Stoeglehner (2012) go so far as to say that if HEIs desire to act as change agents, customizable educational programs must be put in place that involve co-research with local and regional communities. Another option could be to focus on content by balancing curriculum that utilizes

novel approaches to teaching traditional topics. For example, Riley (2011) suggests that engineering and social justice topics should be combined in the context of thermodynamics. The Colorado School of Mines (CSM) has created an educational space relevant to sustainable development by building a foundation with a Humanitarian Engineering curriculum (Mitcham and Muñoz 2010).

2.1 The Broad Perspective of ESD Programs

Understanding the complex transformation of education to include sustainability could be represented by life cycle methods. Klöpffer et al. (2008) describes life cycle sustainability assessment (*LCSA*) as: $LCSA = LCA + LCC + SLCA$. Where life cycle assessment (*LCA*), life cycle cost assessment (*LCC*), and social life cycle analysis (*SLCA*). Each term itself requires further reductionist analysis and study. For example, Finnveden et al. (2009) describe *attributorial* properties (focused on description of environmental properties of a life cycle and its subsystems) versus *consequential* properties (focused on the description of the effects of changes within the life cycle) when performing LCA. Considering these levels of complexity are not common in peer-reviewed literature. In addition, topics such as justice, philosophy, and gender studies, which could be considered components of SLCAs, are largely excluded from traditional engineering programs.

How can stakeholders (i.e. HEIs) truly assess the benefits of HESD programs when they are seen as both complex and ‘fuzzy’ at the same? The application of ‘boundary work’ (Clark et al. 2010) and well-placed ‘boundary objects’ (Star and Griessemer 1989) could initiate a forum for open discussion about the benefits of HESD programs. A ‘boundary object’ can be a physical artifact that promotes discourse and engagement. As a more abstract example, Wenger (1998,

2000, 2010A &B) expands on the idea of social learning via three constituents: 1) communities of practice (e.g. professional societies), 2) the boundary process among them and 3) the identities that are shaped via participation. When conversation among different communities of practice does not occur naturally boundary objects become more critical to help promote discussion.

Along with a boundary object(s), resulting action can be described as 'boundary work'. Effective boundary work may involve constructing and managing opportunities for multiple stakeholders to engage in shared action (e.g. Clark et al. 2002). ESD is a grand challenge that can be broken down into focuses areas for appropriate regional or community implementation and sub focus areas such as Higher Education for Sustainable Development (HESD) and Engineering Education for Sustainable Development (EESD). This research is novel in that it demonstrates that graduate students can create (and therefore demonstrates how to create in local community) these types of objects with respect to HESD and EESD. As an academic example, Fenner et al. (2005) have established a program with five faculty members that in the span of a decade (2003-current) have developed a considerable body of knowledge (pers. comm. 2015).

Fenner et al. (2005) have packed a curriculum in the course of one year! Lucena et al. (2010) suggest that meaningful community based project work could take place over longer periods of time and with consistent engagement. Additional communication with CSM faculty has suggested that successful work in actual *Global South* communities can involve over a decade of time (pers. comm. 2010). Recent communication suggests there are more prominent programs (Jensen 2015) that are lesser-known but maintain educational components that are suggested as critical to EESD programs.

2.2 Relevance to the HEI that was Studied

Previously at CSM, Lucena et al. (2010) illustrate the importance of community, as a component of development while suggesting that engineering problem solving (EPS) that focuses only on technical competence is inadequate for sustainable community development. Lucena et al. (2010) prompt undergraduate student engineers to question how EPS approaches may or may not be appropriate in the context of sustainable community development. Another term that could be used to describe ‘off-the-shelf’ approaches to working with community could also be called *canned engineering*. *Canned engineering* means memorized facts and book like approaches to solving problems that may form an engineer-centric or previous standard solution to project, ignoring either creativity, human or community elements that could provide for a more equitable solution. EPS is valuable for many engineering technical tasks and provides for the basis of standards of practice. Lucena et al. (2010) expand curriculum around EPS that prompts students to consider the complex elements of how EPS interacts with community. Finally, Schneider et al. (2008) posed a convincing argument for strengthening of sustainable development curriculum at CSM and demonstrated actionable outcomes that include; new courses, seminar, and education that impart philosophy relevant to the field of HESD.

CSM student feedback suggests that interest in strong sustainability (e.g. Neumayer 2003) is justified when sustainability is presented as a three-pillar concept (i.e. social, economic, and environmental focuses) (e.g. Muñoz 2010 – class consensus). Therefore, minimal effort was spent to assess comprehensive student desires for an ESD program as part of this research; instead action was focused on how to transform the possibility into reality. Students and alumni

have been polled on the importance of the topic of environmental stewardship included in their respective education programs (Table 1).

{Table 1}

	Very Much	Somewhat	Not at All
Graduating Seniors	36%	40%	24%
Alumni	27%	54%	19%

	<i>Very Much</i>	<i>Somewhat</i>	<i>Not at All</i>
<i>Graduating Seniors</i>	36%	40%	24%
<i>Alumni</i>	27%	54%	19%

Table 1 suggests an increase (5%) in perception that environment stewardship is completely lacking (more so in recent graduates vs. alumni), however, of the polled participants between years 2010-2011, 81% and 76% of alumni and graduating seniors recognize the importance of some form of environmental stewardship education component respectively. One senior CSM Division of Engineering student wrote as part of a Senior Design project broader impacts essay, given the question; “How has your education prepared you to confront broader issues with a social, economic and/or environmental challenges?”

“As we are faced with a world culture that revolves around supply and demand, the process by which we meet that demand must be of greater concern. Engineering colleges need to adapt more aggressively to promote social, economic and environmental responsibility as a vital component of their programs.”

- CSM Senior Design student Spring 2011 Trade Fair program¹

¹ The Colorado School of Mines has made senior design project reports available online via the College of Engineering & Computational Sciences in a report format on the annual Senior Design Trade Fair. Final reports contain broader impact elements typically required of scientific calls for proposals (e.g. National Science Foundation), mechanical.mines.edu, <http://cecs.mines.edu/25763-php>, accessed Spring 2012, 6/14/14 respectively.

The comment was taken out of context but emphasizes a voiced thought that the researcher hears more often in professional activities with students: that STEM-focused education should contain themes of a broad global-culture responsibility (a.k.a. Corporate Social Responsibility in business settings).

It has been the researcher's life experience that suggests undergraduate fields are constantly strained to accommodate the requirements of a basic education (as demonstrated by the continual reduction of core bachelor of science engineering degree credit requirements in the United States²). That is part of the reason why a graduate program could be more appropriate for the topic of HESD or EESD. There might be a natural maturation that occurs within students returning to a HEI's to seek out a different life path beyond undergraduate course work (e.g. Fisk and Ahearn 2006). Further, the National Academy of Engineering considers advancing personalized learning as one of the grand challenges of engineering for the future³. Passionate students' interest in sustainability and environmental topics suggests that an emerging regional model for robust HESD/EESD could be highly relevant to engineering educators. It is also anticipated that student interests will drive aspects of education (Cortese 2003).

Engineering programs that give students the opportunity to interact with local community on social issues create a bridge that fosters the transition from basic STEM education to ESD that is engaged (Stephens et al. 2008), and is proposed herein that creates practical STEAM. As an example, HEIs considering developing HESD degree programs could strive to include communication skills and social sciences (Martin et al. 2006, Martins et al. 2006) as well as fundamental applied science topics such as pollution prevention, waste minimization and cleaner production (Boyle 1999), and could support a move to STEAM. Life experience suggests

² Personal Involvement with the National Council of Examiners for Engineering and Surveying and the American Institute of Chemical Engineer's Career and Education Operating Council's Licensure and Professional Development Committee (2011 to 2014).

³ <http://www.engineeringchallenges.org/cms/8996/9221.aspx>, accessed 10/2011.

that the need to include multidisciplinary training and real world context in HESD/EESD programs is strong for several reasons; STEM practitioners can be stereotyped as poor communicators or deficient or lacking common-sense or soft-skills, by observing the stark contrast of business-as-usual attitudes and practice towards environmental stewardship and health (i.e. lack of strong corporate responsibility), lack of ability of international governments to agree upon means to address global issues harmoniously, witnessing-experiencing unjust social practice, and upon hearing the call from HEI students for engineering education with increased environmental focus. Most recently based on many personal conversations, upon being embedded in customer-service, blue-collar, and labor roles, the author wonders to what extent entitlement is prevalent in student populations. Further, how has the definition and identification of ‘successful’ students changed over the course of time?

3 Methods

At the time of the writing of this research, ten vignettes of action research were undertaken in total, this paper shares two vignettes that comprised interaction and reflexive impact among a HEI (CSM Senior Design Program), the action researcher, and a community setting: the Cole Arts and Science Academy (CASA) a Denver Public School (DPS), co-located with a community garden (Mitchell). These vignettes are shared because the diversity in skill sets addressed by these complimentary settings breaches experiences that could be applied in affluent and Global *South* learning environments. Overall, the many vignettes of research (Jensen 2015) serve as examples of potential HESD programmatic elements and also illustrate community and regional settings that could enhance individualized HESD/EESD education. Ultimately, it is envisioned that a global community would be engaged.

3.1 Action Research

This research was structured around formal and informal interviews that were carried out in academic settings, with local communities, and among professional societies to gain insight into thoughts on education and relationship to sustainability. Personal student journals were kept and quantitative data was captured when it was generated. The well-established field of Action Research (AR, Reason and Bradbury 2001) was applied in exploratory vignettes (i.e. investigating aspects of community that could enhance a HESD/EESD program) and is more commonly known as participatory action research (PAR). The focus of this paper is based around one particular community setting (a community garden).

Exploration (Ben and Dunphy 2008) and participatory (Kindon et al. 2007, Pretty 1995, Kemmis 2006) research methods are common in education (Joy 2007), which can also be principles of AR (Reason and Bradbury 2001). That is, it is participatory research focused on working with the community, the energy and environmental sectors, interested HESD experts, and many educational institutions. AR is circular in nature and ongoing (Jensen 2015, Sonneborn 2005).

AR was chosen as the applied method because students and educators desire robust programs that provide for sustainability science, practitioners, and researchers (pers. comm. CSM 2009-2012). A specific focus or aim of AR is to initiate and promote change that is dynamic and has been referred to as a spiral process dynamically making use of reflection, hypothesis, action to move towards a goal (Jensen2015). In the context of the GAP, five priority action areas have been cited as; 1) advancing policy, 2) transforming training and learning environments, 3) build capacities of engineers and educators, 4) empower and mobilize youth, 5) accelerate sustainable solutions at a local level. The AR presented herein provides for an example that

strongly adheres to the second through fifth priorities by; created two novel learning environments, utilized higher education students to empower and mobilize primary school children, and built a sustainability education tool at the community level.

3.2 Data Collection

Data was collected qualitatively as well as quantitatively. Unstructured interviews and conversation was administrated when interacting with community and professional organizations. Quantitative measure was obtained when appropriate. Examples include; eco-indicator points of a material or process (a number that indicates the environmental impact), engineering design results, and sales of produce at a weekend farmers market.

Vignette 1 describes community gardens as experiential and literacy learning settings. This vignette of research was observed based on interaction with a DPS teacher and involvement by developing interactive and innovative curriculum largely based on the use of community gardens. *Vignette 2* describes how the researcher took insights gained from *Vignette 1* and developed, along with other HEI STEM students at CSM, a ‘learning station’ that could be used by a wide array of educators to teach concepts of sustainability and STEM principles (called from this point on as: the STEM-sustainable science station or S⁴).

SimaPro was utilized for product based life cycle assessment and was available on the CSM computer network. The Eco-indicator 99 database was used as the information resource for product design case study.

4 Data – Vignette Details

Vignette 1 represents a two-year collaborative project that also involved working with community for a summer. In year one, a primary school teacher and the researcher developed

and taught weekly innovative environmental and science literacy classes at a public school in sessions called, infusion. These classes were electives for mixed groups of 1st grade - 8th grade students. The concepts were taught in the classroom, in a community garden near the school, and were based on experiential learning (Cantor 1997) and discovery learning (Bruner 1961) principles. In total three infusion sessions were taught that also incorporated hands on activities (in the classroom and community garden), group activities, and reporting.

Sustainability topics, STEM concepts, relevant social dimensions (e.g. social justice, dimensions of community), and basic reading and writing skills were taught in the context of a garden (Murphy 2003). The primary teacher's focus was on the impact that these experiences had on participatory emergent readers and writers (PERW, Morell 2006). PERW are students with emerging grade-level literacy skills (i.e. not fluent or independent with these skills). The gardening process was taught on many levels; such as learning about cultivars, garden planning, selection of seeds, germination methods, the continued care techniques applied to crops and land, and appropriate behavior in a community spaces.

The action researcher also supported STEM concepts by tying in stewardship topics that included environmental management techniques (e.g. composting, vermicomposting), and the fundamentals of how energy is transformed. When possible, hands on measurement techniques were used to teach energy concepts by use of a light meter and an electricity usage monitor.

4.1 Environment as an Integrated Context

The effectiveness of using community gardens as a classroom could be evaluated using concepts borrowed from 'Environment as an Integrated Context' (EIC), a framework that

gauges and quantifies educational impacts of teaching in natural settings (Lieberman and Hoody, 1998).

“EIC-based learning is not primarily focused on learning about the environment, nor is it limited to developing environmental awareness. It is about using a school’s surroundings and community as a framework within which students can construct their own learning, guided by teachers and administrators using proven educational practices.”

-Lieberman and Hoody (1998)

Skelly and Bradley (2000) was given as a reference to support the embodied knowledge and support that teachers share on the topic of using school gardens for educational purposes. Murphy and Schweers (2003) report that teachers overwhelmingly found that: “gardening programs led to more conducive learning environments.” Literature reviewed to support this research strongly suggests that EIC has positive impacts and would provide for the education needs of students with emergent grade-level literacy skills (Murphy 2003 and Skelly 2000).

4.2 *Seeds of Economy and Innovation*

The entrepreneurial aspects of this work are viewed as foundational at a time when unemployment rates (unadjusted) in the United States were nearly double (~9.6%) in 2010 compared to years 2002 to 2008⁴. Public school students were introduced to fundamental business concepts by selling produce from local markets, urban gardens and that they had grown on their own (Table 2). Market data from these types of studies is sparse, but could serve as inputs for sustainable food system studies, possibly linked to community and educational outcomes.

{Table 2}

1	2	3	4	5	6	7	8	Totals	Average	Per Participant
---	---	---	---	---	---	---	---	--------	---------	-----------------

⁴ United States Bureau of Labor Statistics, <http://www.bls.gov>, accessed August 2013.

Cash (\$)	144	126	169	31	14	5	52	44	674	84	18.7
Produce (\$)	40	82	81	11	30	21	24	29	310	39	8.6
Profits (\$)	103	133	88	20	44	-11	35	156	569	71	15.8
Lbs. sold	85	110	98	20	57	10	80	60	520	65	14.4
Lbs.	4	47	65	5	3	20	20	33	196	25	5.5
Donated											
Indv. Sales	53	60	40	10	20	5	30	26	244	31	6.8
Participants	6	5	3	5	5	4	5	3	36	5	1.0

	WEEKS								<i>Totals</i>	<i>Ave.</i>	<i>Per Participant</i>
	1	2	3	4	5	6	7	8			
<i>Cash (\$)</i>	144	216	169	31	14	5	52	44	674	84	18.7
<i>Produce (\$)</i>	40	82	81	11	30	21	24	29	310	39	8.6
<i>Profits (\$)</i>	103	133	88	20	44	-11	35	156	569	71	15.8
<i>Lbs. Sold</i>	85	110	98	20	57	10	80	60	520	65	14.4
<i>Lbs. Donated</i>	4	47	65	5	3	20	20	33	196	25	5.5
<i>Indv. Sales</i>	53	60	40	10	20	5	30	26	244	31	6.8
<i>Participants</i>	6	5	3	5	5	4	5	3	36	5	1.0

4.3 Involving HEI and ESD Students in Community Gardens

Teaching in community gardens or in coordination with public schools allows HEI ESD students to gain experience in applied community settings that include cultural differences that are not contained in traditional classroom settings, and could be preparatory for working with larger programs such as Engineers Without Borders. The practice of agriculture alone connects botany, regional climate and environmental sciences. The connection of two-way student interactions also provides inspiration and human connections to possible career and education paths.

In urban areas, the optimization of resources could be practiced with the use of water meters, scales to weigh produce and by the incorporation of novel concepts such as vertical agriculture or hydroponic systems. Inner city areas have been targets for improving economics and healthier styles of living (Tieg et al. 2009) for sometime. A suspect enabling aspect of this vignette of research is the fact that the researcher lived in the area, was part of the process to revitalize a community garden, found partnership with a teacher, and therefore was an integral stakeholder in the community.

4.4 Vignette 2 The Challenge of Incorporating ESD into a STEM HEI

Teaching sustainability concepts in higher education is a relatively new concept. Davidson et al. (2010), Allen et al. (2006) and Allen and Shonnard (2012) all describe programs to incorporate sustainability concepts into the engineering curriculum. However, because of the ambiguity in defining the term ‘sustainable engineering’, there is little consensus in the engineering education community as to how it should be taught (Allenby et al. 2009).

Traditional disciplines seem to want to develop their own definition of sustainability and educational content (Allen and Shonnard, 2012). Despite these leaders exceptional ability to promote discussion, action and course work, focused degree programs elude widespread validity. It appears that many education efforts that the researcher has become familiar with fall short of robust efforts to teach sustainable development in terms of strong sustainability (Neumayer 2003) challenged by what Lozano et al. (2013A & 2013B) echo as the failing of Newtonian and Cartesian mental models; “which relegate learning and action to reductionist thinking and mechanistic interpretation”.

Individual disparate focuses do not provide appropriate venues for holistic approaches to address the needs of HESD/EESD learners. An outline of the complex topics often cited as part of sustainable development can be found online in the (UNESCO): Teaching and Learning for a Sustainable Future web site⁵.

4.5 Higher Education Outreach – Beyond the Traditional Graduate Setting

As a part of *Vignette 1*, the researcher and a CASA teacher developed an idea for an experiential learning tool (Fig. 1A). Over a two-year period, the concept was adapted to be appropriate for learning at a STEM focused HEI (Fig. 1B). In the first year, the researcher worked in the public school and in the community defining need and developing a prototype. In year two, the education tool was incorporated into CSM engineering senior design course.

The S⁴ acts as a mobile and reconfigurable learning center that combines the challenge of growing plants, measures environmental conditions and conveys energy concepts. Using the S⁴, energy efficiency and garden science topics were presented appropriate for the student audience. Conversation with education outreach thought leaders suggests that target ages of 12 to 14 as key ages to engage students on the topics of STEM.

{Figure 1}

⁵ http://www.unesco.org/education/tlsf/mods/theme_a/mod02.html, accessed 6/20/13.

In *Vignette 2*, the conceptual (i.e. prototype) design was presented to CSM Senior Design students by the action researcher who re-emphasized the role of community collaboration, two-way communication and sustainable engineering design principles (Chiu et al. 2007). A Senior Design class design team was challenged to improve the S⁴ design using Life Cycle Analysis (LCA) and Design for the Environment (DfE) paradigms (e.g. Fig. 2). The HEI Senior Design students in *Vignette 2* were tasked to come up with a S⁴ design with a lower LCA score than the original design concept from *Vignette 1*. The CSM students were successful in the refinement of the S⁴ (Figs. 1C/D) at the end of Year 2. Finally, senior design students were taught higher concepts of economy-innovation-grant writing by applying to the United States Environmental Protection Agency's P3 program that is purposed to sponsor opportunity for HEI transformational entrepreneurs.

LCA is a systems tool-technique that can be used to assess designs via functional units (e.g. Lee et al. 1995 and Srivastava 2007, outputs in Fig. 2). Determining the boundaries or spheres

of influence in which the functional unit interacts is a key aspect of performing LCA (Lee et al. 1995). This is very similar to how system boundaries are identified in traditional engineering curriculum.

{Figure 2}

The main focus of *Vignette 2* was to explore how to bring rigorous and quantitative ESD curriculum to an HEI reflexively based upon community interaction. This was partly accomplished by immersion of the action researcher in processes that have also been termed as service learning or learning by doing project work (Shön 1987). As a focus point, the concept of the S⁴ design was inspired by interaction with and based upon the needs of a community.

5 Discussion

The primary lesson learned from *Vignette 1* of this research was that intense challenges to the formation of successful collaborations exist, explicitly due to interdisciplinary nature of ESD research and change of management during periods of collaboration. The researcher believes that Harkavy et al. (2005) accurately describes three elements of a successful collaboration as

containing purpose, process, and product. Harkavy et al. (2005) defines positive process between HEI and community partners as:

“..... a successful partnership should be highly democratic, egalitarian, transparent, and collegial. Higher education institutions should go beyond rhetoric of collaboration and conscientiously work *with* communities, rejecting a unidirectional, top-down approach, which too often describes the actual practice of university-community interaction. The higher education institution and the community, as well as members of both communities, should treat each other as ends in themselves, rather than as means to an end. That is, the relationship itself and the community partners and their welfare (not developing a specified program or completing a research project) should have preeminent value. The collaborative should be significant, serious and sustained, beneficial to both the institution of higher education and the community, and lead to a relationship of genuine respect and trust.”

- Harkavy et al. (2005)

This *process* element of successful partnerships best describes what was observed in *Vignette 1* of this research. For example, the introduction of a new individual to the project, as well as a change in public school management, changed the egalitarian nature of the collaboration. This eventually led to a community partner expressing ‘top down’ lack of respect, distrust, and resulted in bias towards a research participant. The researcher suspects that funding sources that provide for significant means for one of the community based non-profits tried to implement control over this research. Because of this outcome, new boundaries and hierarchies were created which presented challenges for successful interactions. Resilience within CSM was able to manage change and provide for an outcome that supports some of the thoughts shared by Harkavy et al. (2005). This was accomplished by providing for a new community partner when the governance structure changed (not allowing for the initial public school partner to continue as a participant). An informal meeting made possible by the principles set forth by the community partner (without the introduced top down bias) aided in the preservation of a vested research partner’s desires and wishes without detrimental impacts to both *Vignette 2* participants, again in-line with Harkavy’s thoughts.

Lucena et al. (2010) go into great detail about how contextual listening is an important part of contributing to community. The action researcher found that listening enabled (or allowed for) non-destructive outcomes when working with a willing partner and with available resources, notably including appropriate mediation when required. It was concluded that outside influence and top down management practices can be destructive to existing collaborations during AR. Graduate action researchers should explicitly note that exploratory efforts are not well resourced – often resources and significant financial input originate from the initiating investigator (much like how public primary educators in the United States can and do support classrooms with their own pay).

The greatest challenges came from outside actors that could not be clearly identified but had the power and ability to influence bias and promote project disruption. Finally, in some cases, the impacts of outreach may be difficult to assess. Government contacts also made note of this challenge in policy based work and suggested means such as Fig. 3 (i.e. a logic model) as a basis to derive substantive analysis. Researchers may have to innovate in order to develop their own means of assessment. Projects with significant aspects of social-community interaction could require review and working knowledge of fields-methods that are not contained in fundamental engineering curriculum.

The primary lesson learned from *Vignette 2* is that reflexive action research involving community can have an impact on HEIs-graduate students and that rigorous STEM principles can be incorporated as design paradigms. An overview of *Vignette 1* and *Vignette 2* are summarized in a logic model presented as Fig. 3. The value of outcomes in Fig. 3 may be difficult to quantify. It is the researcher's contention that outcomes of this work support the inter-

generational equity and philosophical outcome that is often recounted as a definition of sustainability (Brundtland 1987).

{Figure 3}

A critical aspect of performing research is connecting with the reflective thoughts. The action researcher was challenged not only from an academic perspective but more so from self-improvement and personal growth perspectives. Significant input from mentors was required to promote internal (reflexive and reflective) thought in order to promote professional development. The researcher could tell that this aspect of the research was emphasized based on feedback from mentors and community. It is concluded that administratively, promoting these activities is a major challenge and that education, practices, and educational tools to promote them are required.

Aspects of the action researcher's personal skill set that were improved include; 1) timeliness, 2) focus on recognizing community centric memes in order to adjust behavior found to be acceptable specific to these settings – therefore promoting collaboration, 3) the ability to initiate and drive conflict resolution, 4) taking a stand on the graduate students ultimate goals in a reasonable and professional fashion in part by voicing expertise in professional settings and via action by “taking a place”, 5) scholarly writing skills, 6) grantsmanship, and 7) the ability to provide for mentorship instead of relying upon it.

When considering program development, peer review literature gives several deeper examples of the impact AR can have on individual scholars⁶ (Fisher and Phelps 2006, Senge and Scharmer 2006, Kemmis 2010, Nordin et al. 2010, Kemmis 2011). Following through with exploratory aspects of AR can be difficult, however, the internalization and reflection process was found to reveal workable outcomes during challenging situations and forced the researcher to constantly evaluate and differentiate the needs-wants of individual roles, partner relationships, and interactions. All of these elements provided for a continuous reflective self-improvement process (Schön 1987).

6 Conclusions

It was concluded that graduate students can take significant steps to strengthen a conversation on how and why an EESD degree program could be developed. As a part of that conclusion, the policy component of the UNESCO GAP makes use of mixed research methods that can be used to better convey pros and cons to academic administrators.

⁶ Cohen and Morrison (2007), Chapter 14: Action Research provides for a shorter presentation than the [Handbook of Action Research](#) (Reason and Bradbury 2013). This chapter explores the evolution, many schools of thought, and practically applied examples in the field of Action Research.

It is concluded that if HESD programs can be launched, that action researchers continue to identify challenges and develop mechanisms for continuous improvement. Conversation with faculty suggested that researchers not get caught up in the complexity of the lingo associated with the field of AR approaches when considering implementation but instead focus on frameworks, assessments, and outcomes that provide for tangible discussion points geared towards implementation. Expertise in the teaching practices would certainly follow, consider the meme, “if you build it, they will come”.

Disclaimer

The views, results, and communication expressed and contained in this research submission do not necessarily represent the views of the Federal Energy Regulatory Commission or of the United States of America.

Acknowledgements

Gratitude and thanks to the HESD & EESD communities of practice including reviewers from J. Clean. Prod. Research was made possible by; NSF grants - #1048263 & #DUE-0630888, GK12 #'s; 0231611 & 0638719, the CSM Sustainability Committee, CASA in the DPS, CSM Graduate Student Travel Grants, the Colorado Governor's Energy Office (now simply the Colorado Energy Office), the Colorado Graduate Grant Fund, Leppert Associates, the US EPA, the US DOE's National Renewable Energy Laboratory, Boulder County, Jefferson County, the Front Range gardening community, Denver Urban Gardens, the Regional Transportation District, and the Employment Firm. Thanks to; Chad Crane for use of the interpretation of a functional unit figures, Peer Technologies, Dr. Cameron Turner, Dr. David Muñoz, Dr. Barb Moskal, Dr. Chuck

Courtad, Mathew Panning, and Blue Moon Enterprises LLC. For those requesting anonymity, your contribution is greatly appreciated.

Actors involved in the networks described herein do not claim binding partnership, the actions and results presented are best described in the terms of an anonymous NREL employee, that described the laboratory's culture, as "...here (and along the Front Range), we walk the talk". Without a car and when conducting this research I biked, walked and tool public transportation for over three years!

Tables and Figures

Table 1: Perception of extent that Mines education contributed to the development of skills/abilities to stewardship of the environment.

Table 2: Adoption of data from entrepreneurial focused participatory results with K-8 students at farmers markets, inner city Denver. Results include; program cash available on a weekly basis (Cash), supplemental produce purchased from local markets (Produce), tallied profits (Profits), weights of sold-donated produce (Lbs. Sold, Lbs. Donated respectively), sales transactions (Indv. Sales), per participant metrics are calculated from weekly averages divided by average number of participants.

Figure 1: A) Original conceptual design proposed by researcher and CASA teacher used to construct a bill of materials, **B)** Resulting S4 generation one design, **C)** Second generation S4 design provided by a CSM Senior Design class, **D)** Second generation S4 education instrument displayed at Senior Design trade fair.

Figure 2: The middle bar represents the SimaPro life cycle analysis single output score of the original S⁴ design generated using Eco-Indicator 99 V2.07. A comparison was made with two other indoor green house support structures (Jensen 2010).

Figure 3: A Logic Model (Inputs, Outputs, Outcomes) that reviews the Exploratory Research project with Denver-Golden community. This could be an example thesis analysis tool for Engineering for Sustainable Development Program outcomes. The major outcomes are considered to be; 1) education capacity that supports innovative experiential and discovery learning programs, 2) DfE education course-project work in a HEI, 3) strengthened community involvement, 4) has created a feed back loop by connecting higher education to public education, and enabled double looping learning principals (Agyris 2002), 5) and has created entrepreneurial opportunities on multiple scales that extend beyond the education model presented here.

References

mechanical.mines.edu (accessed Spring 2012)

<http://cecs.mines.edu/25763-php> (accessed June 2014)

<http://cor-dump.appspot.com/nsf.html>

<http://www.engineeringchallenges.org/cms/8996/9221.aspx> (accessed October, 2011)

<http://www.bls.gov> (accessed August, 2013)

Agyris, C., 2002. Double Loop Learning Academy of Management. Learning & Education. 2, 206-19.

Allen, D. T., Murphy, C. F., Allenby, B., & Davidson, C., 2006. Sustainable engineering: a model for engineering education in the twenty-first century? Clean Technol. Environ. Policy 8, 70-71.

Allen, D. T., and Shonnard, D., 2012. Sustainable Engineering: Concepts, Design, and Case Studies. New York: Prentice Hall.

Allen, D. T., and Shonnard, D. R., 2012. Sustainability in chemical engineering education: Identifying a core body of knowledge. AIChE J., 8, 2296-2302.

Allenby, B., Murphy, C. F., Allen, D., & Davidson, C. 2009. Sustainable engineering education in the United States. Sust. Sci. 1, 7-15.

Benn, S., and Dunphy, D., 2008. Action research as an approach to integrating sustainability into MBA programs: an exploratory study. J. of Manage. Ed.

Bielefeldt, A.R., 2011. Incorporating a Sustainability Module into First-Year Courses for Civil and Environmental Engineering Students. J. Prof. Iss. Eng-ASCE 137, 78 -85.

Blake, T. K., 2005. Journaling; An active learning technique. Int. J. of Nurs. Ed. Scholar. 2.

Boyle, C., 1999. Education, sustainability and cleaner production. J. Clean. Prod. 7,83-87.

Bruner, J. S., 1961. "The act of discovery". Harvard Ed. Rev. 1, 21-32.

Brunekreef, B., & Holgate, S. T., 2002. Air pollution and health. The Lancet 360, 1233-42.

Bruntland Commission. "Our common future" (1987).

Cantor, J. A., 1997. Experiential Learning in Higher Education: Linking Classroom and Community. ASHE-ERIC Higher Ed. Report No. 7.

Carroll, A. B., and Shabana, K. M., 2010. The business case for corporate social responsibility: a review of concepts, research and practice. *Int. J. Manag. Rev.* 1, 85-105.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D.H., Jäger, J., and Mitchell, R.B., 2003. "Knowledge systems for sustainable development." *PNAS* 14, 8086-8091.

Cebrián, G., Grace, M., and Humphris, D., 2015 "An Action Research Project for Embedding Education for Sustainable Development in a University Curriculum: Processes and Prospects." *Integrative Approaches to Sustainable Development at University Level*. Springer International Publishing, 707-720.

Chiu, M. C., & Okudan, G. E., 2010. An Investigation of the Applicability of DfX Tools During Design Concept Evolution. Department of Industrial and Manufacturing Engineering, Pennsylvania, accessed; http://www.personal.psu.edu/mzc148/APIEMS07_849.pdf, no longer available online.

Clark, W.C., 2002. "Science and technology for sustainable development: Background document to the Mexico City Synthesis Conference on Science, Technology and Sustainable Development." Report 9, (International Council for Science, Paris).

Clark, W.C., and Dickson, N.M., 2003. Sustainability science: The emerging research program. *PNAS*. 14, 8059-8061.

Clark, W.C., 2007. Sustainability Science: A room of its own. *PNAS*. 104, 1737-1738.

Clark, W. C., Tomich, T. P., Van Noordwijk, M., Dickson, N. M., Catacutan, D., Guston, D., & McNie, E. C., 2010. Toward a general theory of boundary work: insights from the CGIAR's Natural Resource Management Programs.

Cohen, L. M. L. and Morrison, K., 2007. Research methods in education. 6th edition.

Corcoran, P.B., Walker, K.E. and Wals, A.E.J., 2004. Case studies, make-your-case studies, and case stories: a critique of case-study methodology in sustainability in higher education. *Environ. Ed. Research* 10, 7-21.

Cortese, A.D., 2003. "The critical role of higher education in creating a sustainable future". *Planning for Higher Education*. 3, 15-22.

Coyle, E. J., Jamieson, L. H., & Oakes, W. C. 2005. EPICS: Engineering projects in community service. *Int. J. Eng. Ed.*, 1, 139-150.

Davidson, C.I., Hendrickson, C.T., Matthews, H.S., Bridges, M.W., Allen, D.T., Murphy, C.F., Allenby, B.R., Crittenden, J.C., and Austin, S. 2010. "Preparing future engineers for challenges of the 21st century: Sustainable engineering." *J. Clean. Prod.* 7, 698-701.

Davies, J., 2011, GreenBiz Salary Survey 2011, Published online November 14, 2011, (accessed 10.13.2013).

Declaration, Barcelona. "Engineering education in Sustainable Development Conference Barcelona." 2004.

Finnveden, G., Hauschild, M., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., and Suh, S., 2009. "Recent developments in life cycle assessment." *J. Environ. Manage.* 1-21.

Fenner, R. A., Ainger, C. M., Cruickshank, H. J., & Guthrie, P. M., 2005. Embedding sustainable development at Cambridge university engineering department. *Int. J. Sust. Higher Ed.*, 3, 229-241.

Fenner, R. A., Ainger, C. M., Cruickshank, H. J., & Guthrie, P. M., 2006. Widening engineering horizons: addressing the complexity of sustainable development. *Proc. ICE-Eng. Sust.*, 4, 145-154.

Fisher, K., and Phelps, R., 2006. Recipe or performing art? Challenging conventions for writing action research theses. *Action Research*, 2, 143-164.

Fisk, D. J., and Ahearn, A., 2006. Creating policy analysis skills in postgraduate engineering for sustainable development. *J. Clean. Prod.* 9, 946-951.

Gardner, C. A., Acharya, T., & Yach, D., 2007. Technological and social innovation: a unifying new paradigm for global health. *Health Affairs*, 4, 1052-1061.

Godfray, H., Charles, J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., and Toulmin, C., 2010. "Food security: the challenge of feeding 9 billion people." *Science* 327, 812-818.

Goodland, R., 1995. The concept of environmental sustainability. *Annu. Rev. Ecol. Syst.*, 1-24.

Harkavy, I., 2005. University - assisted community school program of West Philadelphia: Democratic partnerships that make a difference. *New Directions For Youth Development*, 107, 35-43.

Herr, K., & Anderson, G. L. 2014. *The action research dissertation: A guide for students and faculty.* Sage Publications.

Hotez, P. J., 2008. Training the next generation of global health scientists: a school of appropriate technology for global health. PLoS neglected tropical diseases, 2, e279.

Jansen, L., 2003. "The challenge of sustainable development", J. Clean. Prod. 3, 2231-2245.

Jawahir, I. S., Rouch, K. E., Dillon, O. W., Holloway, L., & Hall, A., 2007. Design for sustainability (DFS): new challenges in developing and implementing a curriculum for next generation design and manufacturing engineers. Int. J. Eng. Ed. 23, 1053.

Jensen, C.D., 2010. Sustainable Design Project: Innovating Urban Green School Outreach and Life Cycle Analysis. Division of Engineering, Colorado School of Mines, Golden CO.

Jensen, C.D., NSF GK-12 Fellow, July 22nd, 2011. Presentation: Extending "What is Energy?" to Middle School, Colorado School of Mines, Golden CO.

Jensen CD, Hall LA. 2011. "Urban Sustainability Outreach and Green School Education: Gardening, Agricultural Science, Engineering, & Life Cycle Analysis." International Congress on Sustainability Science and Engineering (ICOSSE).

Jensen, CD., 2015. "Graduate Student Action Research to Help Fill Gaps for Formal Engineering Education for Sustainable Development Program Formation: Vignettes As Action." Paper #112. Nesbit, S. & Froese, T. M. (Eds.) Proc. EESD15: The 7th Conf. Eng. Ed Sust. Develop., University of British Columbia, Vancouver, Canada. June 9-12.

Jones, P., Selby, D. and Sterling, S. 2010. Introduction. In Jones, P., Selby, D. and Sterling, S. (Eds.), Sustainability education: perspectives and practice across higher education. Publications Limited, London.

Johnson, N., Reidy, L., Droll, M., & LeMon, R. E. 2012. Program Requirements for Associate's and Bachelor's Degrees: A National Survey.

Joy, M., 2007. Research methods in education (No. 10). Innovation Way, York Science Park, Heslington, York YO10 5BR: The Higher Education Academy.

Kamhi, A. G. 1994. Research to Practice. Language, Speech, and Hearing Services in Schools, 25, 115-118.

Kates, R., Clark, W. C., Hall, J. M., Jaeger, C., Lowe, I., McCarthy, J. J., & Svedin, U. 2000. Int. J. Eng. Ed. & Sust. Sci.

Karatzoglou, B., 2013. An in-depth literature review of the evolving roles and contributions of universities to education for sustainable development. J. Clean. Prod., 49, 44-53.

Kemmis, S., 2006. Participatory action research and the public sphere. Ed. Action Res., 14, 459-476.

Kemmis, S., 2010. What is to be done? The place of action research. Ed. Action Res., 18, 417-427.

Kindon, S., Pain, R., & Kesby, M. (Eds.). 2007. Participatory action research approaches and methods: Connecting people, participation and place. Routledge.

Koolwal, G., & Van de Walle, D., 2013. Access to water, women's work, and child outcomes. Econ. Develop. Cult. Change, 61, 369-405.

Klöpffer, W., 2008. Life Cycle Sustainability Assessment of Products. Int. J. Life Cycle Ass. 13, 89-95.

Lavoie, E. T., Heine, L. G., Holder, H., Rossi, M. S., Lee, R. E., Connor, E. A., ... & Davies, C. L., 2010. Chemical alternatives assessment: enabling substitution to safer chemicals. Environ. Sci. Technol., 44, 9244-9249.

Lee, J. J., O'Callaghan, P., & Allen, D., 1995. Critical review of life cycle analysis and assessment techniques and their application to commercial activities. Resour. Conserv. Recycl., 13, 37-56.

Lieberman, G. and Hoody, L., 1998. Closing the achievement gap: Using the environment as an integrating context for learning. San Diego: State Education and Environment Roundtable.

Lozano, R., Lozano, F. J., Mulder, K., Huisingh, D., & Waas, T., 2013. Advancing higher education for sustainable development: international insights and critical reflections. J. Clean. Prod., 48, 3-9.

Lozano, R., Lukman, R., Lozano, F. J., Huisingh, D., & Lambrechts, W., 2013. Declarations for sustainability in higher education: becoming better leaders, through addressing the university system. J. Clean. Prod., 48, 10-19.

Lucena, J., Schneider, J., & Leydens, J. A., 2010. Engineering and sustainable community development. Syn. Lect. Engineers, Technol. Soc., 5, 1-230.

Manring, S. L. 2014. The role of universities in developing interdisciplinary action research collaborations to understand and manage resilient social-ecological systems. J. Clean. Prod. 64, 125-135.

Martin, B. 2006. Outdoor leadership: Theory and practice. Human Kinetics.

Martins, A. A., Mata, T. M., & Costa, C. A. 2006. Education for sustainability: challenges and trends. Clean Technologies and Environmental Policy, 8, 31-37.

- Mitcham, C. and Muñoz, D., 2010. "Humanitarian engineering." Synthesis Lecture on Engineers, Technology, and Society. 1, 1-87.
- Mochizuki, Y., and Fadeeva, Z., 2008. Regional centres of expertise on education for sustainable development (RCEs): An overview. *Int. J. Sust. High. Ed.* 9, 369-381.
- Morrell, E., 2006. Critical Participatory Action Research and the Literacy Achievement of Ethnic Minority Groups. 55th Annual Yearbook of the National Reading Conference. 55, 60-78.
- Moser, C. O., 1989. Gender planning in the Third World: meeting practical and strategic gender needs. *World development*, 17, 1799-1825.
- Muñoz, David, Class Discussion. Sustainable Engineering Design. Colorado School of Mines, Golden, CO Fall Semester 2010.
- Murphy, J., 2003. Education for Sustainability: Findings from the Evaluation Study of The Edible Schoolyard. Berkeley, CA, Center for Ecoliteracy.
- Murphy, J. and Schweers, E., 2003. Evaluation of a Food Systems-based Approach to Fostering Ecological Literacy: Final Report. Boston, MA, Massachusetts General Hospital, Harvard Medical School.
- Nagel, T., 2005. The problem of global justice. *Philosophy & Public Affairs*, 33, 113-147.
- Nakagawa, M., Bahr, K., & Levy, D., 2013. Scientific understanding of stakeholders' behavior in mining community. *Environment, development and sustainability*, 15, 497-510.
- NAS (National Academies of Science) 2013. Emerging Workforce Trends in the U.S. Energy and Mining Industries: A Call to Action. National Academies Press.
- Neumayer, E., 2003. Weak versus strong sustainability: exploring the limits of two opposing paradigms. Edward Elgar Publishing.
- Nicol, D. J. & Macfarlane-Dick, D., 2006. Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Stud High Educ.* 31, 199-218.
- Nordin, N., 2010. Mobile learning framework for lifelong learning. *Procedia-Social and Behavioral Sciences*, 7, 130-138.
- Oki, T., & Kanae, S., 2006. Global hydrological cycles and world water resources. *Science*, 313, 1068-1072.
- Peer, V., and Stoeglehner, G., 2012. Universities as change agents for sustainability-framing the role of knowledge transfer and generation in regional development processes. *J. Clean. Prod.* 44, 85-95.

Pennington, D.W., Potting, J., Finnveden, G., Lindeijer, E., Jolliet, O., Rydberg, T., & Rebitzer, G., 2004. Life cycle assessment Part 2: Current impact assessment practice. *Environment International* 30, 721-739.

Perez-Padilla, R., Schilman, A., & Riojas-Rodriguez, H., 2010. Respiratory health effects of indoor air pollution [Review article]. *The International Journal of Tuberculosis and Lung Disease* 14, 1079-1086.

Pope, D. P., Mishra, V., Thompson, L., Siddiqui, A. R., Rehfuess, E. A., Weber, M., & Bruce, N. G. 2010. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic reviews*, mxq005.

Prabhat, J., Frank J. Chaloupka, James Moore, Vendhan Gajalakshmi, Prakash C. Gupta, Richard Peck, D. T. Jamison et al. (eds.), 2006. "Disease control priorities in developing countries." *Disease control priorities in developing countries*. Oxford University Press, New York. Chpt-42, 793-816.

Pretty, J. N. 1995. Participatory learning for sustainable agriculture. *World development*, 23, 1247-1263.

Ray, I. 2007. Women, water, and development. *Annu. Rev. Environ. Resour.*, 32, 421-449.

Reason, P., and Bradbury, H. (Eds.), 2013. *The SAGE handbook of action research: Participative inquiry and practice*. Sage.

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., ... & Pennington, D. W. 2004. Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment international* 30, 701-720.

Riley, D., 2011. Engineering thermodynamics and 21st century energy problems: A textbook companion for student engagement. *Synthesis Lectures on Engineering*. 3, 1-97.

Senge, P. M., and Scharmer, C. O., 2006. Community action research: learning as a community of practitioners, consultants and researchers. *Handbook of Action Research: Concise Paperback Edition*, 195-206.

Srivastava, S. K., 2007. Green supply-chain management: a state-of-the-art literature review. *International journal of management reviews*, 9, 53-80.

Schillhorn van Veen, T. W., 2005. International trade and food safety in developing countries. *Food Control* 16, 491-496.

Schneider, J., Leydens, J. A., & Lucena, J. 2008. Where is 'Community'? Engineering education and sustainable community development. *European journal of engineering education* 33, 307-319.

Seuring, S. and Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. *J. Clean. Prod.* 16, 1699-1710.

Schön, D. A., 1987. *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions.* San Francisco.

Skelly, S. and Bradley, J., 2000. School Gardens: Their importance as perceived by Florida elementary school teachers. *Hort. Tech.* 10, 229-231.

Skelly, S. M., 2000. *The Growing Phenomenon of School Gardens: Cultivating Positive Youth Development.* Ph.D. Dissertation. University of Florida Press. Gainesville, Florida.

Sonneborn, C. 2005. *Industry capacity building with respect to market-based approaches to greenhouse gas reduction: US and Australian perspectives.* Ph.D. Dissertation. Murdoch University.

Star, S., and Griesemer, J., 1989. Institutional ecology, 'Translations' and Boundary Objects: Amateurs and Professional in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Soc. Stud. Sci.* 19, 387-420.

Stephens, J. C., Hernandez, M. E., Román, M., Graham, A. C., & Scholz, R. W. 2008. Higher education as a change agent for sustainability in different cultures and contexts. *Int. J. Sust. High. Ed.* 9, 317-338.

Wenger, E., 1998. *Communities of Practice: Learning, Meaning, and Identity.* Cambridge University Press, Cambridge, UK.

Wenger, E., 2000. Communities of practice: the structure of knowledge stewarding. In: Despres, C., Chauval, D. (Eds.), *Knowledge Horizons: the Present and the Promise of Knowledge Management.* Butterworth-Hieneman, Boston, pp. 205-224.

Wenger, E., 2010A. 'Conceptual tools for CoPs as social learning systems: boundaries, identity, trajectories and participation.' Chapter 8 in Blackmore, C. (ed.) *Social Learning Systems and Communities of Practice.* Springer, Dordrecht.

Wenger, E., 2010B. 'Communities of practice and social learning systems: the career of a concept.' Chapter 11 in Blackmore, C. (ed.) *Social Learning Systems and Communities of Practice.* Springer, Dordrecht.

Wiek, A., Withycombe, L., & Redman, C. L. 2011. Key competencies in sustainability: a reference framework for academic program development. *Sust. Sci.*, 6, 203-218.

Willard, M., Wiedmeyer, C., Warren Flint, R., Weedon, J. S., Woodward, R., Feldman, I., & Edwards, M. 2010. *The sustainability professional: 2010 competency survey report.* *Environ. Qual. Manage.* 20, 49-83.

Yergin, D., 2006. Ensuring energy security. *Foreign Affairs*, 69-82.

Yuan, X., and Zuo, J., 2013. A critical assessment of the Higher Education For Sustainable Development from students' perspectives—a Chinese study. *J. Clean. Prod.*, 48, 108-115.