D-Lab and MIT IDEAS Global Challenge: Lessons in Mentoring, Transdisciplinarity and Real World Engineering for Sustainable Development

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Abstract

This paper reflects on the Massachusetts Institute of Technology's D-Lab and IDEAS Global Challenge pedagogy over the past 14 years (2002–2015). The MIT IDEAS Global Challenge, a program of the MIT Public Service Center, is an annual invention and entrepreneurship competition that awards up to $10,000 per MIT team for innovations and service projects that positively impact underserved communities. IDEAS student teams work with a community partner on projects that are designed to improve the quality of life globally. Since its founding in 2002, IDEAS has awarded more than $600,000 to 132 teams. D-Lab Water, Sanitation, Hygiene and Environmental Innovations for the Common Good (D-Lab WASH + ENV) is a MIT course offered for the past 10 years within a curriculum of over 20 D-Lab classes in international development. This author has mentored several hundred student teams that have entered the IDEAS Global Challenge, mostly through this course D-Lab WASH + ENV, including 26 winning teams. Eighty-one percent of these IDEAS winning teams have been led by women students. This is a model of the kind of program that can bring gender parity to science, technology, engineering and math (STEM) disciplines while nurturing the "whole student." In common with the wider family of D-Lab courses, the D-Lab-WASH + ENV course is structured around experiential learning and real-world engineering. This paper links the Engineering Education for Sustainable Development (EESD) conference themes with the D-Lab/IDEAS pedagogy in terms of key concepts: **mentoring**, **transdisciplinarity** and **real world engineering**. It ends with challenges and recommendations.

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W. Leal Filho and S. Nesbit (eds.), *New Developments in Engineering Education for Sustainable Development*, World Sustainability Series,
DOI 10.1007/978-3-319-32933-8_19

Keywords
Mentoring · Transdisciplinary · Transdisciplinarity · Real world engineering · STEM disciplines · Experiential learning · New pedagogy · Gender · Gender parity

1 Introduction

Two Massachusetts Institute of Technology (MIT) programs, D-Lab and the IDEAS Global Challenge (referred to throughout this article as "IDEAS"), are examples of outstanding programs that re-imagine engineering education for sustainable development. Concurrently, they do an exemplary job at supporting women's success in science, technology engineering and math (STEM) subjects, as well as nurturing the "whole student." This paper addresses the Engineering Education for Sustainable Development (EESD) conference themes and the D-Lab/IDEAS pedagogy in terms of key concepts: **mentoring**, **transdisciplinarity** and **real world engineering**. It articulates a vision of re-imagined engineering education, identifies challenges faced by the D-Lab and IDEAS programs at MIT, and ends with recommendations.

2 What Is D-Lab?

Founded in 2002 by Amy Smith, Senior Lecturer in MIT's Mechanical Engineering Department, D-Lab is an MIT program that challenges students to use their science, engineering, technology, math plus social science and business skills to tackle a broad range of global poverty issues. D-Lab seeks to build a global network of innovators to design and disseminate technologies that meaningfully improve the lives of people living in poverty. The program's mission is pursued through interdisciplinary courses, technology development, and community initiatives, all of which emphasize experiential learning, real-world projects, co-creation with community partners, and scalability (the ability to scale up technological innovations to ensure health and well-being to millions of people).

D-Lab students have developed innovative technologies and processes such as community water testing, water and wastewater treatment systems, human-powered agricultural processing machines, medical and assistive devices for global health, clean-burning cooking fuels made from agricultural and other bio-waste, all carried out with community partners who co-conceive, co-design, co-build and co-implement these innovations within underserved areas.

In its first decade of existence, D-Lab developed 18 MIT courses with about a dozen offered during any given academic year, for example: D-Lab Development; D-Lab Design, D-Lab Dissemination, D-Lab Energy, D-Lab Schools, D-Lab Health and D-Lab Mobility. (A full listing of D-Lab courses is here: http://D-Lab.mit.edu/courses/). Many of these courses are cross-listed with academic departments: for example Mechanical Engineering, Architecture, Urban Studies and Planning and Sloan School of Management. In addition, they provide credit towards major and minor courses of study. All D-Lab classes are connected to communities around the world including partnerships in Brazil, Nicaragua, Guatemala, Ghana, Peru, Cambodia, Tanzania, Botswana, El Salvador, Uganda, India, Zambia and Nigeria. Most D-Lab classes offer an opportunity for field work. Students may pursue undergraduate research or other long-term research projects with D-Lab staff members.

Most D-Lab instructors are experienced development-practitioners and dedicated teacher-mentors. Few are tenured faculty. The emphasis is applied, experiential, inter-disciplinary (crossing two or more academic department boundaries) and trans-disciplinary (crossing many disciplinary boundaries and including all relevant stakeholders to co-create a holistic approach). The implicit sustainable development goal of these endeavors is to learn about and to improve the well-being of present and future generations and in so doing, to protect and preserve the earth. Some in-coming students say they elect to attend MIT because of D-Lab. Many students find their D-Lab class(es) and field experience to be life-changing and a high-point of their MIT careers.

D-Lab has grown into a powerful force for innovation on campus and a widely recognized program of creativity, innovation and entrepreneurship around the world. It has grown by leaps and bounds over its 14-year history and is comprised of many diverse initiatives, including—International Development Innovators Network (IDIN), Comprehensive Initiative for Technology Evaluation (CITE), D-Lab Scale-Ups, Youth Outreach, and a core group of instructors, staff and development-practitioners. This paper is not meant to speak for the entire D-Lab community, but rather to offer the author’s reflections based on her own D-Lab teaching and learning experiences.

3 D-Lab Dissemination

3.1 Background

The author’s association with D-Lab began in 2003 when she, together with Amy Smith, the founder of D-Lab, and Heather Cruickshank, Senior Lecturer in the Civil, Structural and Environmental Engineering Division of the Department of Engineering, Cambridge University, collectively taught a new course, Design for Developing Countries (SP753/SP722) at Cambridge University. In that same period, Amy Smith began teaching a new MIT course in the fall term, D-Lab Development, which was an introduction to international development, with the option for field work during January’s Independent Activities Period. Subsequently, Design for Developing Countries, the Cambridge University graduate level course, was reworked into an MIT undergraduate class, D-Lab Design. Concurrently, the author was invited to teach D-Lab Dissemination, which was the third "D" of the original D-Lab trilogy of courses (i.e. Development, Design and Dissemination).

The MIT course catalogue description of D-Lab Dissemination (SP723, later re-catalogued as EC715/11.474) reads as follows:

> D-Lab III is the third in the D-Lab trilogy of courses on "Development," "Design," and "Dissemination" focusing on disseminating innovations among underserved communities, especially in developing countries. Students acquire skills related to building partnerships and piloting, financing, implementing, and scaling-up a selected innovation for the common good. The course is structured around MIT competitions: IDEAS Global Challenge, $100K, Deshpande IdeasStream Innovation Showcase, and outside competitions…

3.2 Early Years of D-Lab Dissemination

For five years, from spring 2006 to spring 2010, D-Lab Dissemination focused on all manner of innovations in any discipline. Always, the emphasis of the class was supporting students as they formulated their creative idea and mentoring them through the creative process of bringing that seed idea to fruition. Entering the MIT IDEAS Global Challenge or some other competition or grant application process was always the student deliverable for this class. D-Lab Dissemination's term project requirement was that the student formed a team and entered IDEAS or some equivalent competition(s) of their choice. Team projects are common in all D-Lab classes. The requirement to enter IDEAS or some other appropriate competition was, to my knowledge, unique to the D-Lab Dissemination class (although of course, any MIT student is eligible to enter the IDEAS competition).

3.3 Refocus of D-Lab: Dissemination to D-Lab WASH and Environmental Innovations

Meanwhile, the D-Lab program's course offerings were growing rapidly. After the first five years of teaching D-Lab Dissemination, the author decided to refocus the D-Lab Dissemination course from innovations in any domain to projects exclusively in her area of expertise—water, sanitation, hygiene and environmental innovations. Thus, the course was re-named D-Lab: Water, Sanitation, Hygiene and Environmental Innovations for the Common Good (EC.715/11.474), or D-Lab WASH + ENV for short.

3.4 Small but Beautiful—and Award-Winning

This narrow focus has kept D-Lab: WASH + ENV classes small, but always we have subscribed to the philosophy of "small is beautiful." While we have been small, with class sizes of about 10 students per term forming about four to five teams, we have been "beautiful" insofar as these teams have won many IDEAS and other competitions. In fact, teams mentored though this class, plus a few other teams the author mentored before this first class existed, have won 26 prizes in IDEAS competitions from 2002 to 2015. Of 132 winning IDEAS teams total over this period, teams this author has mentored represent 20 percent of all IDEAS winners.

4 IDEAS Global Challenge

4.1 IDEAS

As has been mentioned, one of the unique features of the D-Lab Dissemination/D-Lab WASH + ENV course is that the core deliverable for the course is to enter the IDEAS Global Challenge or some other suitable competition. Most students in the class elect to enter IDEAS. IDEAS is an annual competition held each spring at MIT. IDEAS stands for key themes of the competition: **I**nnovation, **D**evelopment, **E**nterprise, **A**ction, and **S**ervice. Awards are given for innovations that address community development challenges at home and around the world in underserved communities, engaging community partners to co-create solutions for identified community needs. Winning teams receive a grant of up to $10,000 to help fund the implementation of their service project. Founded in 2001, IDEAS complemented the pre-existing MIT $100K Competition, which tended, historically, to emphasize for-profit business innovation, but which has since expanded into multiple thematic areas all centered on entrepreneurship. Since 2002, the MIT IDEAS Global Challenge has awarded more than $600,000 to 132 teams. Offered through the MIT Public Service Center and sponsors, IDEAS is in MIT's best tradition of creative problem-solving, hands-on and experiential learning and entrepreneurial spirit to further positive change through innovation.

4.2 IDEAS Winning Teams from D-Lab Dissemination/D-Lab WASH + ENV

The author mentored two winning teams in the first IDEAS competition in 2002 and four winning teams in the 2014 and 2015 IDEAS competitions. In these intervening years, the author has mentored a total 26 winning IDEAS teams—20 % of all winning teams (Appendix 1). Many of these teams have innovated in the domain of water, sanitation, hygiene and environmental projects. Eighty-one percent of the winning teams the author has mentored have been led by women students. Since we are operating in the elite, male-dominated domain of engineering innovation and entrepreneurship, this is a solid manifestation of gender-inclusive pedagogy that we should seek to nurture and advance. In addition, some teams enter multiple competitions and concurrently or sequentially enroll in other D-Lab classes, sometimes in order to further develop the same team concept. Through this they get exposure to other disciplines and D-Lab instructors. Even if they only take one D-Lab class, students are aware that there is an entire MIT system of innovation and international development practice. So it is important to acknowledge multiple mentors and supporters for any one class's success. (See Appendix 2 for brief descriptions of five selected teams).

5 Mentoring, Transdisciplinarity and Real World Engineering: Re-imagining Engineering Education—Emphasizing the "Whole 'Trans' Student" Learning in Real World Communities and Environments

Three core pedagogical concepts—**mentoring**, **transdisciplinarity** and **real-world engineering**—have informed and contributed to the success of the D-Lab WASH + ENV class.

Therefore, in each of the three thematic sections below—**mentoring**, **transdisciplinarity** and **real-world engineering**—I begin by defining my terms. Then, because this University of British Columbia conference, Engineering Education for Sustainable Development, is about re-conceptualizing engineering education for sustainable development, and because likewise, D-Lab and the IDEAS are MIT programs that re-conceptualize engineering education, I will next illustrate various aspects of these core pedagogical framing concepts as they pertain to D-Lab WASH + ENV and IDEAS by discussing key themes within each conceptual framework.

In defining my terms, it should also be mentioned that although the D-Lab and IDEAS programs do not always explicitly use the terminology of sustainable development, D-Lab and IDEAS very much align with sustainability values, for example, as expressed in the best-known definition of sustainable development: "meeting the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development, 1987). Below, I discuss the D-Lab and IDEAS conceptualization of engineering education for sustainable development, that is to say, the "whole student" learning in real world communities and environments, based on the author's experience over the past two decades of researching, teaching and mentoring at MIT generally and through active engagement with D-Lab and IDEAS specifically.

5.1 Mentoring

Mentoring is often thought of as advising or training a younger individual to help them realize their potential. In my opinion, mentoring is about nurturing a student's own creative capacity. While it encompasses training and advising, its focus is on being a role model. As female role models are less numerous in the fields of science, technology, engineering and math, I believe it is particularly important for female students and other "minorities" to receive female and other "minorities" mentoring.

Some of the dimensions of mentoring within the D-Lab WASH + ENV class and IDEAS include the following.

- *Value: Listening, Supporting and Enabling Students*: Given the rigors of technical science and engineering education, there is limited opportunity in the traditional classroom and core curriculum, which focuses on mastering fundamentals, for students to gain the confidence to propose their own ideas and see them through to fruition. Listening and supporting the students in all that they do and giving them the opportunity in the classroom and in the wider world to express and innovate is key to this pedagogy.
- *Value: Nurturing Inclusivity and Cooperation*: the D-Lab WASH + ENV class and the IDEAS competition provides opportunities to nurture values of inclusivity, cooperation and service, engendering a sense that we are all involved in solving these global problems by working together.
- *Value: It Doesn't Matter if You Win or Lose*: Every team which completes the process of entering and presenting their idea to the class, then subjects it to the scrutiny of the judges and the public at the IDEAS annual showcase gets invaluable experience in conceptualizing and taking steps towards realizing their dream idea. So regardless of whether they win an award, students make huge gains by embracing this opportunity and moving their idea forward.
- *Value: Walking the Talk*: The instructor attempts to be a role model who is also engaging in innovation and entrepreneurship in international development.

5.1.1 Mentoring the "Whole Person"

The "whole person" is not merely rational, but has an identity, a cultural inheritance, a place of origin, a creative imagination, core relationships, an emotional life, a spiritual dimension and a system of inherited values. D-Lab WASH + ENV mentors the "whole person" through an approach that recognizes and tries to advance the entire sweep of human knowledge, wisdom, experience and expression in arts, humanities, science and engineering, not only discipline-specific science/engineering learning.

5.1.2 Challenging the Student to Research and Develop an Idea or Project That They Love

Students are mentored in creating an idea or project that they are passionate about, that they could imagine giving themselves to for at least one academic term, for a year, for their university years or even for their lifetimes. The students attracted to D-Lab WASH + ENV are those who are passionate about exploring global water and environment projects.

5.1.3 Focus on Students' Learning Outcomes as a Complement to Teacher-Prescribed Teaching

Learning that is individualized and personalized fosters self-realization, problem-solving, communication, critical thinking and creativity. The key is to help a student foster her/his own ideas and to invest her/his whole self in realizing that idea. This suggests that the role of the teacher involves a comparable creative process that mirrors the process of the student's own learning.

5.1.4 Engagement of University Students with Vastly Different People/Cultures Living in Poverty

This engagement fosters profound and life-altering experiences that enable the student to know and experience herself/himself and the world clearly. University students who encounter vastly different people and cultures living in poverty are exposed to potentially profound, life-altering, deep-learning experiences.

5.1.5 Experiential Learning

Dewey's pedagogical model described in *Experience and Education* centers on the principle of learning through personal experience, also referred to as "the new education"—which includes "free activity, learning through experience, acquisition of skills and techniques which make direct vital appeal, making the most of opportunities of present life, acquaintance with the present world" (Dewey 1938, pp. 19–21). This exemplifies Dewey's role as the father of experiential learning.

5.1.6 Teaching and Learning While Sitting Together in a Small Circle

There is a lot of fascination, rightly, with the power of the internet to revolutionize education. MITx, edX among other on-line course platforms, are pioneering in that space. Meanwhile, the teaching/learning style of D-Lab and IDEAS is also pioneering a new pedagogy, which is both entirely contemporary in its use of digital media and at the same time is age-old. As on-line courses dive into the future, providing education for thousands of students at a time, the D-Lab WASH + ENV model is diving into the person, to recall that teaching and learning begins with the person, then their family, and hopefully extends to a teacher and her/his students. This relationship is a face-to-face mutual exchange of teaching/learning, curiosity, challenge, support and love. As in family, so too the educational highlights of our lives hopefully involve knowing and learning from specific teachers. It may be that when we sit together in small circles of such teachers/learners, that in these relationships we find the most profound meaning.

5.2 Transdisciplinarity

The Oxford English Dictionary defines **transdisciplinary** (adjective) as: "pertaining to more than one discipline or branch of learning; interdisciplinary" (OED 2013).

For example, "A recent workshop jointly sponsored by the American Association for the Advancement of Science and the U.S. Department of Energy has been attempting to lay **transdisciplinary** foundations for a federally supported research programme on the impact of increasing atmospheric carbon dioxide content" (*Nature*, May Vol. 3, No 1/2, 1979).

Transdisciplinarity (noun) is a derivative that expands the notion of transdisciplinary to create a holistic approach or unity of knowledge beyond any single discipline (Jean Piaget may have coined the first use of this term in 1970). Transdisciplinarity not only assumes the necessity of collaboration across academic disciplines, but importantly, engages with all the relevant stakeholders, not least, those most affected by the research. As a consequence, transdisciplinarity engages different ways of knowing; generating new knowledge and helping collaborators understand and incorporate the results or lessons learned by the research (see: Wickson et al. 2006).

I like the "trans" in transdisciplinarity. "Trans" as a prefix means: "across, through, over, to or on the other side of, beyond, outside of, from one place, person, thing, or state to another" (OED 2013).

We need language and concepts that take us beyond divisions, across to the other side of borders. "Trans" helps take us there both in our imaginations and in our daily routines.

So, with "trans," transdisciplinary and transdisciplinarity, we have this suite of meanings:

1. Across to the other side, beyond, from one place, person, thing or state to another;
2. Interdisciplinary;
3. Seeking a holistic unity of knowledge;
4. Collaboration among relevant stakeholders, not only among academics;
5. Engaging with the people affected by the research;
6. Embracing different ways of apprehending the world.

These meanings of "trans," transdisciplinary and transdisciplinarity reveal different nuances of meaning. Transdisciplinarity provides a conceptual framework that helps us comprehend and practice sustainable development. But transdisciplinarity is a cumbersome and academic term. I like "trans" as a simplification for the entire set of meanings above.

In my earlier work, I put forward the concept "co-evolutionary design for development" suggesting a suite of characteristics that parallel the multiple meanings of trans/transdisciplinary/transdisciplinarity (Murcott 2007). The D-Lab community refers to "co-creation" and "creative capacity building"—the idea in all cases being that innovation and scale-up of new technologies and approaches to bring basic health and well-being to millions of people is a relational, creative and collaborative process with multiple stakeholders across and beyond disciplines and borders.

5.2.1 Mind, Hand, Heart and Spirit

Since its founding in 1861, MIT has had as its motto "*Mens et Manus*, "Mind and Hand." "Mind and Hand" captures competencies that MIT has been historically famous for—science and engineering, basic and applied research, theory and practice. IDEAS and the D-Lab family of classes are also exemplars of "Mind and Hand." They embody science. They embody engineering. In recent years, it has been proposed that MIT change its motto from "Mind and Hand" to "Mind, Hand and Heart." There is a parallel initiative on campus: Mind + Hand + Heart http://mindhandheart.mit.edu/ to enhance mental health and well-being of the MIT community. I would suggest that a new MIT motto: "Mind, Hand, Heart and Spirit" is expressive of a broader "trans person" and "whole person" that includes not only the mind/body part, but also includes emotional, spiritual and moral dimensions. Heart and spirit may be uncomfortable territory in a scientific/engineering environment. But if we seek to train the "whole person," then we cannot ignore these dimensions. MIT should seek to cultivate graduates who are emotionally, spiritually and morally literate, as well as technically literate.

5.2.2 Diversity, Inclusion and Gender Parity

Bringing heart and spirit into the MIT identity would mean that we include and welcome a greater awareness of service to address global poverty, especially the poverty of invisible women and children. How do you bring heart and spirit (and women and children) into the community? One answer could be "inclusion." In terms of gender, one aspect of inclusion must be parity of women and men on the MIT faculty and administration, ideally sooner than one or two generations from now. What about in the next decade? It could be done … if there were the political will. Iceland, Norway, Sweden and Finland have taken concrete steps to achieve gender parity in their academic and all other institutions. If they can do this, so can MIT and other top engineering universities in the USA and around the world (Zahidi 2013).

5.3 Real World Engineering

This leads directly to "real world engineering" which refers to applied engineering projects conducted by teams from universities or research institutes working with local communities around the world. It is a specific application of experiential learning. D-Lab challenges technically-trained students to use their math, science, engineering, social science, business and other skills to tackle specific global poverty issues. For the D-Lab teams that enter IDEAS, real world engineering is linked with real world competition. The requirement for the D-Lab WASH + ENV class is to either enter IDEAS or any other competition(s) of their choice or to write a proposal to a relevant agency, non-profit or foundation in order to fund their idea. Entering IDEAS is the most popular choice among students from D-Lab WASH + ENV.

5.3.1 Situating Learning Beyond the University in Complex, Real World Contexts

D-Lab pedagogy is especially interested in engaging students in complex real-world contexts of extreme poverty. By the very fact of their being in university, university students are largely privileged. Exposing them to poverty challenges them to explore their own values and ways of knowing more deeply.

Engineers are problem solvers. Yet engineers-in-training can often be given trivial assignments, or expected to contribute only small or insignificant parts to a much larger puzzle, the meaning of which is never explained. The D-Lab pedagogy expects students to grapple with real world questions of our time and to situate them in a holistic, cultural context. How can our talents as engineers-in-training be applied to contribute to a better life for impoverished people and communities? Can we address climate change via a tree-planting social enterprise or a biofuels innovation? Can we alter patterns of materials and energy use to enable a sustainable world for present and future generations?

5.3.2 New Modes of Engaged Teaching/Learning in Small Face-to-Face Groups of Non-hierarchically Organized Teachers/Learners Solving Real World Challenges

Traditional engineering education has a narrow conception of achievement. This involves being right, being smart, and smarter than others, moving up the career ladder. It's about the achievement of degrees, status, titles, grants, money and power.

The author has been immersed in MIT culture for 28 years, a culture largely but not exclusively comprised of engineers and scientists who are innovative, entrepreneurial, individualistic and technology-focused. I relate to that culture both as an insider and outsider. I understand MIT culture from the inside because I am innovative and entrepreneurial. I experience MIT culture as an outsider for several reasons—I am a woman who embraces her feminist and feminine identity, I am people and community-focused, rather than individualistic. I agree with psychologist and professor, Carol Gilligan, who writes that "the moral injunction that emerges repeatedly in interviews with women is an injunction to care, a responsibility to discern and alleviate the 'real and recognizable trouble' of this world" (Gilligan 1982). I believe the Western tradition is seriously flawed in its exclusion of women's and other outsiders' voices and that the way we "meet the needs of the present generation without compromising future generations from meeting their own needs" is through connection with peoples universal aspirations for basic well-being, security, education and opportunity for themselves and their families. I engage in engineering projects that help other people. Women and men are attracted to these real-world projects. My inclination is to embrace my outsider status. Maybe it helps me think outside of the box. What I love about the D-Lab and IDEAS pedagogical models is that they are "being the change we wish to see in the world" (Mahatma Gandhi). These programs walk the talk of engineering for sustainable development.

5.3.3 Complex Systems Thinking and Complex Problem-Solving in the Face of Poverty

Complex systems thinking and complex problem solving in the face of extreme poverty has been the hallmark of D-Lab/IDEAS. A key concept in the D-Lab/IDEAS universe of systems thinking in the face of extreme poverty is the importance of collaboration, variously referred to as co-creation (Prahalad and Ramaswamy 2002), co-evolutionary design (Murcott 2007), human-centered design (IDEO 2015), user research framework (Smith and Leith 2014) and "Design with the other 90 %" (Smithsonian Cooper Hewitt National Design Museum 2015). Human relationships are an often side-lined aspect of complex systems thinking. This new pedagogy seeks to engage all people in the competencies of systems thinking, design and dialogue.

To give an example—the IDEAS competition requires each team to have a clearly defined community partner. This often overlooked dimension of partnership and of equality in the problem engagement phase of design involves the human dimension into the complex system. We are no longer concerned exclusively with system optimization, which maybe relevant but inconsequential in holistic engineering that emphasizes our relationship to our fellow human beings.

5.3.4 Strategic Thinking

Strategic competency in international development involves leadership. The starting point is the inclusive notion that "we are all in this together." Students in the D-Lab/IDEAS circles are challenged to co-create and implement projects and facilitate change in collaboration with community partners. Here, the contribution and challenge of D-Lab/IDEAS is how to implement projects and facilitate change in cultures and environments that are vastly different from the ones we are used to. To give an example—MIT students are privileged and generally have not grown up in extreme poverty. Most of us who are in a tertiary educational environment have had the privilege of access to such conveniences as piped water and flush toilets within a system of centralized water and wastewater treatment systems. However, in communities without safe water and improved sanitation, women and children may spend a significant part of their day carrying water from its source to their homes. These women and children, especially girls, often don't go to school and have been largely invisible to engineering designers and infrastructure builders. So, this raises the question of what would engineering leadership look like if we sought to co-evolve water and sanitation solutions with these still largely invisible communities and people, such as underprivileged women and children? Would the engineering designs be piped water and flush toilets? Would the most practical and achievable engineering designs be centralized water supply and end-of-pipe wastewater discharge systems? Should we design community-based and decentralized systems? Should we design water and sanitation systems that return clean water to aquifers, rivers, fields and forests? What systems would be embraced by communities that fit within their cultures and geographies?

6 Challenges and Recommendations

Below are several significant challenges encountered in teaching at MIT and the author's recommendations for addressing these challenges:

- *Tenured Faculty vs "the Rest"—Hierarchal and "Caste" Divisions in the Ivory Tower:* D-Lab/IDEAS are not typically led or supported by tenured academic faculty from science, technology, engineering and math (STEM) disciplines, some of whom may think that the extra-curricular and possible international travel component of these projects is a distraction from more high-priority graduate and post-graduate research, publication and achievement. This divides some tenured faculty, especially at elite research institutions like MIT, from the lower caste non-tenured lecturers, instructors, international development practitioners and staff who run these experiential learning experiences.

Dewey describes traditional education:

> Call up in imagination the ordinary school-room, its time-schedules, schemes of classification, examination and promotion, of rules of order and I think you will grasp what is meant by [traditional education]… The main purpose or objective is to prepare the young for future responsibilities and for success in life, by means of acquisition of the organized bodies of information and prepared forms of skill which comprehend the material of instruction. Since the subject matter as well as standards of conduct are handed down from the past, the attitude of pupils must, upon the whole, be one of docility, receptivity and obedience… while teachers are the organs through which pupils are brought into effective connection with the material. Teachers are the agents through which knowledge and skills are communicated and rules of conduct are enforced (Dewey 1938, p. 18).

Applying Dewey's system to tertiary education, that traditional system includes the tenured faculty system. Speaking only from my own limited experience in the present day context at MIT, many tenured STEM faculties seem to have limited field experience or competency with poverty and international development. Some may find these activities superfluous, extra-curricular or simply outside of their professional research purview. My modest proposal is that "the system" needs to include other "trans" voices from outside the borders of academia. We need to bring the outsiders in.

- *Do Women Teachers Lead to Women's Success in Engineering Leadership*?: Top MIT leadership, including the MIT Institute Community and Equity Office, embrace equity and inclusion, as per the recent recommendation to create a MIT Compact on what we aspire to as a community and what we expect of one another as MIT community members. (Bertschinger 2015). One dimension of inclusion is gender equity. MIT has made some significant strides to increase the number of women faculty. Between 1995 and 2011, the percentage of women on the engineering faculty has increased from 7 to 16% and the science faculty from 8 to 19 % (MIT 2011). Yet classroom instruction is still an overwhelmingly male enterprise.

6.1 Gender Parity

Gender parity is still lacking in STEM faculties and administration at MIT and around the world. But if gender parity is yet to be realized in engineering education and the other STEM disciplines, if we consider gender parity as well as service to the poor as important strategic objectives, then it is necessary to consider those rare examples where gender parity and service to the poor are already being achieved in STEM institutions. We have examples at MIT, such as the D-Lab and IDEAS programs, where women and other "minorities" are present in "trans" teams, and where women and "minorities" are attracted in great numbers. These programs, classes and development projects and design innovations are "being the change we wish to see in the world." The D-Lab and IDEAS programs provide rare examples of gender parity, with equal or even greater numbers of women and other "minorities" in successful leadership roles within MIT's Schools of Science and Engineering.

Gender parity is not only the ratio of the number of female students enrolled at primary, secondary and tertiary levels of education to the number of male students in each level. It must also be the ratio of the number of female faculty and staff teaching/learning with students to the number of male faculty and staff teaching/learning with students. When a discipline lacks women teachers, it lacks role models for women to enter and shape that field.[1] I would relish an engineering program that supports women and men in an inclusive environment of gender parity.

Without intending it, the percentage of IDEAS winning student teams led by women mentored by this author is an astonishing 81 %. In a N.Y. Times editorial,

[1]The **Gender Parity Index (GPI)** is a socioeconomic index usually designed to measure the relative access to education of males and females. In its simplest form, it is calculated as the quotient of the number of females by the number of males enrolled in a given stage of education (primary, secondary, etc.). It is used by international organizations, particularly in measuring the progress of developing countries. The Institute for Statistics of UNESCO also uses a more general definition of GPI: for any development indicator one can define the GPI *relative* to this indicator by dividing its value for females by its value for males. For example, some UNESCO documents consider gender parity in literacy. http://unstats.un.org/unsd/mdg/Metadata.aspx?IndicatorId=9.

Lina Nilsson, of the Blum Center for Developing Economies at UC-Berkeley asks: "How do we attract female engineers?" and "Why are there so few female engineers?" She says many reasons have been offered—workplace sexism, lack of female role models, stereotypes of women's innate technical competency, the difficulties of combining tech careers and motherhood. Fixes have been suggested—mentor programs, student support groups, targeted recruitment, diversity commitments. But one solution stands out for its elegant simplicity. At UC-Berkeley, "**if the content of the work itself is made more societally meaningful, women will enroll in droves. That applies not only to computer engineering but also to core traditional, equally male-dominated fields like mechanical and chemical engineering**." (Nilsson 2015). My experience teaching D-Lab WASH + ENV, and the success of women in engineering leadership in innovating with "ideas that help other people," is the hallmark both of D-Lab and IDEAS. The D-Lab and IDEAS experience at MIT is identical to that of Nilsson's at UC-Berkeley's Blum Center for Developing Economies.

One additional question is whether having a woman teacher supports success of women in engineering leadership? In "Do Faculty Serve as Role Models? The Impact of Instructor Gender on Female Student," (Bettinger and Long 2005) use a comprehensive, longitudinal dataset of nearly 54,000 students to complete one of the first large-scale studies aimed at estimating the impact of faculty on the outcome of students. They report that female instructors do positively influence course selection and major choice in some disciplines, thus supporting a possible role model effect. The findings provide insight into the possible impacts of policies designed to increase female representation on college faculties. If women teachers lead to women students' interest in a particular academic discipline, then a corollary could be that lack of women teachers helps explain the gender gap between women and men in STEM disciplines. This suggests that one remedy is gender parity in the faculty of STEM departments. One would think that there should be tremendous interest on the part of the MIT faculty and administrators in understanding the reasons for women's significant representation in the D-Lab and IDEAS contexts, both at the leadership and student prize-winning levels. The purpose of Appendix 1 is to document one instance of this success using the example of D-Lab WASH + ENV/IDEAS, where one woman mentor provides a role model to women students particularly and to all students generally.

This paper constitutes the author's reflections on the paradigm of the D-Lab and MIT IDEAS Global Challenge and pedagogy as it relates to engineering education for sustainable development. This is a work in progress. Comments, critiques and ideas are welcome.

Acknowledgements The author would like to acknowledge the D-Lab and IDEAS Global Challenge instructors, staff and students who have contributed to making these programs such a dynamic, joyful, egalitarian and supportive learning environment, and without whom the successes described here would not have been possible.

Appendix 1

MIT Award-Winning Student Teams Advised by Susan Murcott. More info on specific IDEAS teams is available on the MIT IDEAS Global Challenge Website: http://globalchallenge.mit.edu/teams/past.

The table below lists the 31 winning teams (26 IDEAS teams plus 5 other team awards), along with the project location, the type and amount of the award, the team leader, D-Lab-WASH class participants and/or other students on that team.

Year	Team name	Project location	Competition[a] award	Team leaders, D-Lab-WASH class participants and/or team members
2015	Change: WATER	Jordon	$10,000 IDEAS Award	Grace Connors, Jessie Press-Williams, Diana Yousef
2014	Clean water clean data	Ghana, Guatemala	$7500 IDEAS Award	David Taylor, Natasha Wright, Marcelo Giovanni
2014	My H_2O Team	PR China	$1500 IDEAS Community Choice Award. $39,000 National Geographic Air and Water Quality Fund Award (2014)	Xiaoyuan “Charlene” Ren
2014	Ways2Clean	Bangladesh	$3000 IDEAS Award	Tamanna Islam Urmi
2013	Spouts of water	Uganda	>$50,000 from competitions, grants and fund-raisers	Seul (Kathy) Ku, Suvai Gunasekaran, Hannarae Nam
2013	Hope in flight	Ghana	$7500 IDEAS Award	Coyin Oh and Yiping Xing
2012	OpenIR	Indonesia	$7500 IDEAS Award	Arlene Ducao, Juhee Bae, Ilias Koen, Abdulaziz Alghunaim
2012	wecyclers	Nigeria	$7500 IDEAS Award	Bilikiss Olatoyosi, Alex Fallon, M. Hickman, Emily Boggs
2011	AQUA	Tanzania	$5000 IDEAS Community Choice Award	Peter Kang and Junyun Song
2011	Kosim water keg	Ghana, Guatemala	$10,000 Global Challenge Award	Joanna Cummings, Chris Schulz
2011	SafeWaterWorld	Chile	$7500 IDEAS Award	Samantha O’Keefe
2010	The grease project	Brazil	$3000 IDEAS Award	Ana Bonomi
2010	My city, my future (ArteRio)	Brazil	$3000 IDEAS Award	Kate Balug & Alix Beranger

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Year	Team name	Project location	Competition[a] award	Team leaders, D-Lab-WASH class participants and/or team members
2010	PieceMeal vendors	Thailand	$1000 Community Choice Award	Kim Liao
2009	Global cycle solutions	Tanzania	$30,000 $100K Award Emerging Markets Track	Jodie Wu
2009	Global citizen water initiative	Tibet	$5000 IDEAS Award	Scott Frank
2007	New DOTS	Nicaragua, India	$5000 IDEAS Award	Angela Kirby, Jeff Blander, Elizabeth Gillenwater, Jose Gomez-Marquez, Minyoun Jang, Aron Walker
2007	Vac-cast prosthetics	Cambodia	$7500 IDEAS Competition	Tess Veuthey
2006	CentroMigrante	Philippines	1st Prize. MIT $100K Sloan Entrepreneurship Competition—Dev. Entrepreneurship Track	Illac Dias
2006	FirstStepCoral	Philippines	$7500 IDEAS Award	Illac Dias
2006	Peanut revolution	Philippines	$5000 IDEAS Award	Illac Dias
2006	Kounkuey design initiative	Kenya	$150,000 International Resource Award for Sustainable Watershed Management (2012)	Chelina Odbert and Jennifer Toy
2006	Synergetic power systems	Lesotho	$225,000 (Only winning student team in this competition in 2006)	Elizabeth Wayman, Amy Mueller, Matthew Orosz, Sorin Grama, Ignacio Aquirre, Perry Hung, Mark Wolf
2006	Synergetic power systems	Lesotho	$125K Ignite Clean Energy Business Competition Winner	Elizabeth Wayman, Amy Mueller, Matthew Orosz, Sorin Grama, Ignacio Aquirre, Perry Hung, Mark Wolf
2005	Parabolic power II (former team name of synergetic power systems)	Lesotho	$2000 IDEAS International Technology Award	Elizabeth Wayman, Amy Mueller, Matthew Orosz, Sorin Grama, Ignacio Aquirre, Perry Hung, Mark Wolf
2005	Solar water disinfection device	Nepal	$2000 IDEAS Award	Deborah Xanat Flores.
2005	Mozambique environmental sanitation initiative	Mozambique	$3000 IDEAS Award	Brian Robinson, Pragnya Alekai + 7 other teammates from DUSP

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Year	Team name	Project location	Competition[a] award	Team leaders, D-Lab-WASH class participants and/or team members
2004	TestWaterCheap	Peru	$5000 IDEAS Award	Brittany Coulbert
2003	Lumbini water solutions	Nepal	$3000 IDEAS Award	Melanie Pincus
2003	MIT UV tube project	Nepal	$2000 IDEAS International Technology Innovation Award	Deborah Xanat Flores
2002	Dlo Prop—Water treatment project	Haiti	$1K Warm-up to the Sloan $50K business competition. Sustainable development category	Luca Morganti
2002	Pure water for nicaragua	Nicaragua	$5000 IDEAS Award	Rebecca Huang
2002	Innovative drinking water technology for bangladesh (Kanchan™ arsenic filter)	Nepal	$5000 International Technology Innovation Award sponsored by the Lemelson-MIT Program	Tommy Ngai, Sophie Walewijk, Roshan Shrestha, Susan Murcott

[a]Competitions Entered:
- IDEAS Global Challenge Competition (2002, 2003, 2004, 2005, 2006, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015)
- MIT $100K Competition (2006, 2009, 2013)
- Lemelson International Technology Award (2002, 2003)
- World Bank Development Marketplace Competition (2006)
- Commonwealth of Mass—$125K Ignite Clean Energy Business Competition (2006)
- International Resource for Sustainable Watershed Mgt Swiss Reinsurance Co. Ltd (2012)
- National Geographic Air and Water Quality Fund Award (2014)

Appendix 2

Descriptions of Selected Award-Winning Student Teams Advised by Susan Murcott. More info on specific IDEAS teams is available on the MIT IDEAS Global Challenge Website: http://globalchallenge.mit.edu/teams/past.

Kanchan™ Arsenic Filter ($5000 in 2002): The *Kanchan*™ Arsenic Filter (KAF) was designed to address arsenic contamination of drinking water at the household scale in rural Nepal. About 350,000 people (35,000 households) in the Terai region of Nepal, where there is high arsenic contamination of groundwater, are exposed to an arsenic concentration above 50 ppb, the national drinking water standard for Nepal. KAFs have been implemented for about two-thirds of that population—about 250,000 people which translates to about 25,000 households In addition to winning one of the original IDEAS awards in 2002, the KAF team has been recognized for a number of other awards including: World Bank Development Marketplace Competition (2003); Wall Street Journal Technology Innovation Award—Environment Category (2005); St. Andrews Prize for the Environment—2nd Prize (2006); Kyoto Water Prize—Top Ten Finalists (2006). A $50K award from Dubai Expo Live in 2014 is enabling the KAF team to reach 20,000 new users in 20 schools in the Bardiya and Kailali districts of the Mid- and Far-Western Terai region in 2015.

Vac-Cast Prosthetics ($7500 in 2007): There are over 25,000 new amputees annually in India as a result of accidents and disease. Despite the availability of free prosthetics and fitting services through several NGOs, only half of these victims receive a prosthetic device that is specifically tailored to their residual limb. One factor for a patient to opt for treatment is whether they can devote the time necessary for the prosthetic fitting and fabrication process in an urban clinic. Conversely, patient throughput by these organizations is limited by the finite resources that they can allocate per patient for the lengthy treatment. Fortunately, there is a novel sand-casting (SC) fitting technique that could increase patient throughput by a factor of five. However, SC cannot be deployed everywhere because it requires a vacuum device that is costly and electricity-intensive. VacCast Prosthetics has developed a simple alternative to this machine that overcomes these limitations. Our technology is unique, easy-to-use, human-powered, costs under $200, is built using materials commonly found in a mechanics shop, uses no electricity, and can be integrated seamlessly with the other sand-casting treatment devices. The Vac-Cast team has developed this device in collaboration with the Jaipur Foot Organization, the world leader in supplying prosthetic limbs and its affiliates to guarantee that our technology will meet the same needs as the electric vacuum machine. The follow-up to this invention and prize was that the team leader, Tess Veuthey, went on to win a Fulbright fellowship to bring this innovation to Cambodia, where there is a high number of amputees.

Hope In Flight ($7500 in 2013): According to a 2010 UN report, 80 % of thewaste generated in northern Ghanaian villages and towns consists of organic waste—most of which are not properly collected or disposed in a safe and healthy manner. One of these villages is Taha, our target community of about 600 people. Such accumulation of waste promotes infectious diseases and the contamination of precious water supplies. Hope in Flight utilizes a low-tech optimizing system that exploits the natural capabilities of the Black Soldier Fly (BSF), a species native to Ghana and other areas in Sub-Saharan Africa, to efficiently process organic waste. BSF larva turns every kilogram of organic waste into 29 US cents worth of protein meal! The collected BSF pre-pupae can be processed into profitable, safe, and nutritious animal feed. *Business Model* Using a technology transfer, Hope in Flight has brought the specialized waste bioconversion systems to entrepreneurs at the University of Development Studies in northern Ghana. The entrepreneurs use the systems to produce protein-rich BSF meal from organic waste, and earn a steady income by selling their farmed product for further processing. Hope in Flight sells the BSF meal as high-quality animal feed to egg, poultry, and fish farmers.

My H_2O ($1500 in 2014): My$H_2O$ is one of the first online crowd-sourcing platforms on water contamination and water quality issues in China <http://www.myh2o.org/>. Although the media in China has become increasingly open about China's environmental problems, the public is still only presented with limited information on water quality. Inspired by the air quality (PM 2.5) campaigns on social media that stirred public reaction and led to greatly increased transparency for air quality information, MyH_2O is one of the first online crowd-sourcing platforms on China's water quality. Created in partnership with China Youth Climate Action Network (CYCAN), MyH_2O aims to promote water risk awareness, increase information transparency and motivate citizen solutions through independent reports of water quality. In addition to their 2014 IDEAS Competition Community Choice award, this team also won a National Geographic Air and Water Quality Fund Award of $39,000 in 2014.

Clean Water Clean Data ($10,000 in 2014): Clean Water-Clean Data's product innovation is the "Smart Spout" that won a $10,000 IDEAS Competition award in 2014. The Smart Spout is a new spigot that can be placed on household water filters to record the frequency and duration of use. The data is read by a smart phone placed on the device. This product allows public health advocates to monitor how text message reminders reflect filter usage patterns. This innovation enables monitoring of consistent and continuous use and provides an objective measure of use, independent of reporting bias. The team intends to pilot their invention in 2015.

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