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Design for the Other 90% and Appropriate Technology: The Legacies of Paul Polak and E.F. Schumacher

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Introduction

Solving problems that differentially affect people living in poverty has always intrigued some engineers. Two authors have had significant influence on why and how engineers might engage with problems of poverty: E.F. Schumacher and Paul Polak. While neither of these two men are engineers, they bring perspectives on global technological systems that challenge conventional engineering practices. Both men use word and deed to articulate visions of technological systems that improve the lives of people living in poverty.

E.F. Schumacher, an economist, critically observed modern industrialization created marked separation between urban and rural areas in developing countries.[1] He called for the development of "intermediate technologies" to improve the quality of rural life. For Schumacher, sound technological development required conserving fossil fuels, respecting the tolerance levels of nature, and affirming human dignity. Schumacher's associates helped him establish the Intermediate Technology Development Group (ITDG) in 1966. The Appropriate Technology movement grew out of a groundswell of interest to develop these intermediate technologies.[2] Development professionals, environmental activists, and social activists gravitated towards Schumacher's broad message.

Paul Polak, a psychologist, identified the limitations of expecting charitable donations and traditional business models to lift people out of poverty.[3] He called for the development of "radically affordable technologies" to increase the incomes of people living in poverty.[4] His experience in marketing and distributing pumps to smallholder farmers in Bangladesh lead him to found International Development Enterprises (IDE) in 1981. IDE relies on market-led forces to create viable technologies. IDE searches for existing consumer demand, designs to specific affordable price targets, and develops innovative last-mile supply chains to deliver products to market. For Polak, developing radically affordable products requires a design revolution. "Design for the Other 90 Percent"[5] serves as a rallying call for designers attempting to develop solutions for problems that differentially affect people living in poverty.

	E.F. Schumacher	Paul Polak
Professional training	Economics	Psychology
Key book	*Small is Beautiful: A Study of Economics as if People Mattered*	*Out of Poverty: What Works when Traditional Approaches Fail*
Technological approach	Appropriate technology Intermediate technology	Design for the other 90% Radically affordable technology
Organization	Founded as Intermediate Technology Development Group (ITDG), now Practical Action	International Development Enterprises (IDE)
Principal design objectives	Delivering a higher quality of life to people living in rural areas	Increasing the incomes of people living in poverty

Engineering educators increasingly look to global problems to increase student understanding the social impacts of engineering solutions.[6-10] Several global service-learning programs have been organized to teach engineering students about "appropriate technology" (such as Peace Corps Master's International Programs at Michigan Tech and MIT D-Lab) or "design for the other 90

percent" (such as Stanford University *Entrepreneurial Design for Extreme Affordability*). Furthermore, engineers are working to change the conversation so incoming engineering students embrace messages that "engineers make a world of difference" and "engineering is essential to our health, happiness, and safety."[11] Effectively organizing engineering education around global problems requires taking greater notice of Schumacher's and Polak's exhortations.

This paper explores Schumacher's and Polak's legacies on engineering practices in developing countries and in engineering education. ITDG, through reorganization as Practical Action, and IDE remain vibrant organizations working in marginalized communities decades after their founding. This paper critically asks two questions:

1) How does each organization bring its founder's vision to various communities?
2) What lessons can engineering educators designing service-learning programs learn from both organizations?

I begin by introducing the *social construction of technology* and *multimodal discourse analysis* as appropriate theoretical frameworks and research methodologies for my research questions. Next I explore Schumacher's and Polak's legacies in how each organization defines poverty, conducts projects, understands community change, and educates the global public. Before concluding, I identify specific lessons for engineering educators designing service-learning programs. Additionally, any existing design organization or service-learning program can use the methodology of this paper to critique their existing efforts.

Theoretical Framework

Exploring design legacies requires theoretical frameworks suited to extended time intervals. The *social construction of technology* (SCOT) provides a comprehensive theoretical frame to analyze engineering design as innovation practices construct technologies. SCOT assumes "every technology is deeply embedded in a continual (re)construction of the world."[12] This framework acknowledges the complex inter-workings in sociotechnical systems. Political priorities, economic conditions, social networks, ecological demands, worldviews, cognitive frames, and technical knowledge interact to constrain, enable, empower, and create opportunities for technological innovation.[13-17] Further, SCOT studies the complexity of innovation systems by identifying both human and nonhuman actors.[18, 19] My analysis extends past single projects to investigate the structural rules of engagement[20] for each organization. Organizations use various forms of stakeholder engagement to support both organizational learning.[21] Organizational learning dynamics influence innovation processes[22, 23] and attitudes towards social change.[24] This paper uses multimodal discourse analysis to illuminate organizational innovation processes.[21]

Multimodal Discourse Analysis

This paper employs *multimodal discourse analysis* to explore how each organization materializes its design ethos within various communities. Both organizations have a long history. Key monographs, countless invited talks, various organizational roundtables, and exhibitions dedicated to organizational design principles shape a complex discourse space. *Multimodal discourse analysis* deals with this complexity by integrating many different communication forms. The research uses multimodal discourse analysis to distill an organization's message. The rigor of multimodal discourse analysis stems from careful reading of the source text, testing interpretations through directly related texts, and situating interpretations in related scholarly literature.[25-29] This study relies on publically available documents.

My data comes principally from organizational artifacts disseminated through the internet. These artifacts include web pages, edited videos, public speeches, organization-authored editorials, strategy documents, organizational social media interactions, and external news reports in various media. I take care to provide media-sensitive readings of each artifact discussed.[25, 26, 29] The large dataset permits using *process tracing* within each case study.[30-32] Process tracing concerns internal validity and gathers multiple observations to support significant conclusions. My analysis incorporates both external commentary on an organization's activities and internal documentation of the same activities. I analyze diverse projects in order to claims about the organization as a whole.[23] To help readers navigate the source data, I use footnotes extensively.

To capture how each organization brings its founder's vision to various communities, I started with organizational homepages. I then navigated various web routes to learn more about featured designs. I focused on projects where the organizations intentionally invite sustained involvement from community members. Next, I triangulated my observations with additional externally generated media coverage and organizational web pages discussing other designs, exploring referenced collaborations where applicable. To incorporate first-person perspectives within the organizations, I read blogs written by a wide range of internal authors.

This study does not incorporate interviews with key stakeholders in the innovation process. While interviews could be used in conjunction with multimodal discourse analysis, the method does not require incorporating interviews. Recognizing the power of first-person accounts, this desk-based study incorporates first-person perspectives found in designers' written reflections. This archival strategy permits the researcher to consider projects across space and time. Reviewing documentation produced five years ago provides different insights than asking someone to reflect on the same events. Similarly, critical analysis of project documentation permits comparing vastly different geographical and team contexts. Undoubtedly a different appreciation of design could be gained from an ethnographic approach. Yet, organizations develop skills of reflective practice through regularly reviewing old projects to learn from past mistakes. Because of reflective practice's disruptive powers, organizations can use reflective practice to shift away from the habits of "normal professionalism" that situate power and agency amongst professionals rather than local communities.[33]

The Legacy of Two Visionaries

Schumacher and Polak promulgated new visions for technological systems. Schumacher contended that the modern industrial system consumed three core substances: "fossil fuels, the tolerance margins of nature, and the human substance."[1] Intermediate technology envisioned a more human industrial system that considered the realities of people living in poverty. These technologies enabled more sustainable rural livelihoods and exposed urban-rural discrepancies. Polak argued the people living in poverty cannot access markets in the modern industrial system, noting billions of people have never seen a Wal-Mart.[4] Polak challenged corporations to develop radically affordable products for emerging consumer markets. Affordable technology offered a new vision for technological systems by challenging designers to develop products that people living in poverty actually need.[3] For Polak, an innovation can be sustainable if and only if people living in poverty purchase the product or service directly. Schumacher emphasized unequal technological distribution while Polak highlighted various market failures in emerging markets.

Contemporary documents from ITDG show how the organization embodies Schumacher's vision. In 2005, ITDG changed its name to Practical Action to communicate the organization's mission and approach more clearly.[a] Practical Action straps "Technology challenging poverty" to core communications, recognizing that technology can sustain, stabilize, and empower livelihood strategies of people living in poverty.[b] The design of high-gloss documents communicating the organization's story[c] and strategic plans of 2007 to 2012[d] reflect attempts to equip the world's poorest people. Every page has pictures of local people in their communities. Furthermore, these pictures nearly always show people with tools in hand, pursuing a rural livelihood, or otherwise in a state of activity. The 2007 Strategic Plan connects Practical Action's history to Schumacher, citing his foresight regarding climate change, inequality, and the need to put technology to work for the world's poorest. Notably, Practical Action's strategy involves using technology to connect the voices of poor farmers to international summits regarding climate change. Connecting the most vulnerable poor to global economic powers lay at the heart of Practical Action's concern for technological justice. As climate change heads an agenda of global concern, Practical Action hopes to model "climate-proofed" development by building resilient livelihoods through grant-funded community infrastructure projects.

Contemporary documents from IDE show how the organization embodies Polak's vision. IDE communicates its mission in a dynamic slideshow located on the organization's homepage.[e] Short sentences in boxes appear with images of smallholder farmers. IDE views income as a basic human right because lack of money restricts access to food and water.[f] To bridge the gap between designers and people living in poverty, IDE treats smallholder farmers as customers. By developing market-based solutions, IDE designers help people exit poverty. In IDE's 2012 Innovation Portfolio, the editors focus on IDE's use of technology and discuss IDE's expansion into West Africa and Latin America. The editors present IDE as an innovator in human-centered design solving vexing problems of economic water scarcity. IDE expands as it builds on previous success in applying "the IDE model" and uses state-of-the-art technologies like GIS to improve designs. IDE catalyzes markets through developing affordable technologies, connecting suppliers with markets, and training villagers in IDE techniques.[g] IDE attracts limited investment to develop sustainable, market-led solutions that help people exit poverty.

	E.F. Schumacher *ITDG - Practical Action*	Paul Polak *IDE*
Contemporary strategy	Reducing vulnerability to climate change	Developing market-led solutions for people in poverty
Contemporary focus	Active rural communities	Farmers accessing water
Identifying communities	Concentrations of inequality	Potentially viable markets

[a] "Practical Action is the new name for ITDG" http://practicalaction.org/history?id=practicalaction
[b] "Technology Challenging Poverty" http://practicalaction.org/technologychallengingpoverty
[c] **34.** Practical Action. *Practical Action: Our Story*. Rugby: Practical Action; 2010.
[d] **35.** Practical Action. *People and Technology: Transforming Lives, Practical Action Group Strategy 2007-2012*. Rugby: Practical Action; 2007.
[e] IDE, Our Story, Mission: http://www.ideorg.org/OurStory/Mission.aspx
[f] International Development Enterprises (2011) *IDE: Cultivating Potential* available at http://www.ideorg.org/IDE/Docs/Download.aspx?docid=1026
[g] IDE, *Introduction to IDE*. http://www.ideorg.org/OurStory/iDE_general_info.pdf

While both Practical Action and IDE attempt to improve the lives of people living in poverty, these organizations have very different visions. Practical Action has strongly retained Schumacher's concerns for inequality. Because Practical Action lobbies expressly around climate change, the charity continually discusses interconnections between the developed and developing world. IDE employs a much more targeted approach, looking at how people living in poverty can earn more money. The IDE model involves training people to capitalize on identified market opportunities. IDE focuses on developing technologies that enable smallholder farmers to get more money out of small plots of land. IDE has strongly retained Polak's vision for sustainable business creation. These different missions could lead to markedly different strategies when working in poor communities.

The Legacy of Working With Smallholder Farmers

Both IDE and Practical Action have a legacy of working with smallholder farmers. IDE grew out of Polak's success selling treadle pumps and small-scale drip irrigation systems to farmers living in poverty. These systems enabled farmers to increase their annual income by selling off-season vegetables.[3] Schumacher articulated that smallholder farmers lacked technologies to add value to their crops.[1] ITDG started by focusing on rural livelihoods, developing tools for post-harvest agricultural processing.[34] Recently, both IDE and Practical Action have completed a project that provided smallholder farmers with treadle pumps. To understand how these organizations share their founder's vision with marginalized communities, I analyze video project reports and supporting project documentation.

Data

IDE's home page featured a 3min13sec video story[h] describing how Veronica, a Zambian farmer, built a house using income from tomatoes. The video opens with footage of Veronica walking through her small plot of land while Veronica uses a Zambian dialect to tell us she participates in IDE's Rural Prosperity Initiative (RPI) and placed a treadle pump on her land. Between 0min52sec and 0min58sec, Veronica says that her income from her first tomato crop was 1330USD while the camera shows her reviewing business documents. At 1min31sec, the setting of the video shifts to a central business region, characterized by cars and various shops. Additionally, at 1min48sec Veronica speaks in accented English when she explains, "The reason I plant tomatoes, peppers, eggplant, and other vegetables is because these are high income crops that IDE identified with its tranings and market identifications." We see various scenes of Veronica having her produce weighed and purchased complete with two shots of an English language receipt at 1min58sec and at 2min20sec. At 2min30sec, the video returns to Veronica in front of her house, thanking IDE for its work with women as she can now help her husband with the household.

Practical Action's website has a devoted media center with a video section. One of their featured videos[i] runs 3min21sec and describes treadle pumps in Nepal. We meet Phool Kumari on her treadle pump as the narrator introduces her as a woman who "claims that vegetable farming can elevate one's social life." In the first 38 seconds, the narrator sketches that Phool previously struggled to feed her family but the 20,000 rupees per season generated by vegetable farming

[h] IDE Visits Veronica's Zambian Farm, uploaded 9 Mar 2010, http://www.youtube.com/watch?v=GvoW8qVdcAc
[i] Treadle Pumps in Nepal, A Story of Phool Kumari, uploaded 18 May 2009, http://practicalaction.org/video/view/treadlepump.

enable her to send her children and sister-in-law to school. We survey Phool's small farm, now equipped with a working hand pump and a treadle pump. At 0min39sec, Phool tells her story in Nepalese. Phool describes how her family used to earn a living through selling logs or waged labor but "now the project has given us land to farm and provided trainings on how to grow vegetables." The video editors present Phool's story as a composite of Phool speaking to camera against video captures of garden scenes. At 2min12sec, Phool discusses the treadle pump explicitly saying, "The treadle pump was a new thing to us before, we didn't know how it would work. But the project came along and they established this treadle pump, they taught us how to use the pump and now it is easy for everyone to use it." Between 2min35sec and 2min46sec, we see Phool and her family in front of a new brick-constructed home. The video closes with Phool saying she has achieved much with the project's support and identifying the additional things she could do with continuing support.

Analysis

At first glance, the two projects appear to have a common technological system: poor mothers (users) receive a treadle pump (tool) to irrigate vegetable farms (expertise). This technological system helped both women move their families out of poverty. Both videos maintain men in the background, focusing on the woman's story. However, several key differences emerge. Veronica in Zambia made an action plan for her garden (0min37sec) whereas Phool received land from the project (1min3sec). Additionally, Phool received training on how to grow vegetables (1min6sec) while Veronica connected with a small business that provides farmers with a better price than the open market (1min45sec). The two organizations also report income differently with IDE favoring using US currency ($1330) while Practical Action reports 20,000-25,000 NR. Furthermore, we know Veronica sells her crops to a business in a more urban area whereas we do not know where Phool sells her crops. Looking at how these organizations mounted these "success" stories, we suspect the two organizations have different strategies for working within marginalized communities.

Core project documents support the claim that the two organizations have different strategies for working within marginalized communities. Practical Action's project carries the name: "Improving livelihoods security of socially-excluded communities in Nepal" (ILISSCON). ILISSCON[j] targets "food insecure and socio-economically marginalised households (HHs) particularly, dalits, ethnic nationalities, women headed HHs and landless or HHs having 1-1.5 kaththas (500 sq metres) of land." These attributes strongly indicate Practical Action works with the *vulnerable* poor. The project organizes beneficiaries into various groups to provide support for leasehold farming. Using FM radio messages and improved transportation structure, ILISSCON connects farmers to existing markets. Through ILISSCON, Practical Action addresses distribution of land, information, and infrastructure while encouraging farmers to use treadle pumps. Conversely, IDE Zambia celebrates a successful market launch of an IDE branded pump to serve smallholder farmers.[k] Market forces dominate as both IDE and Veronica launch successful enterprises. RPI provides affordable irrigation schemes to increase income, improving food security[l] through "(economic) access to that food." Additionally, RPI includes "gender-specific Voice of Customer surveys to determine the necessity and value of gender-

[j] This project is detailed at http://practicalaction.org/livelihoods_IA12900002NEP.
[k] Details of the product launch available at http://www.ideorg.org/OurResults/SuccessStories/Mosi.aspx.
[l] IDE, Our Method, Food Security http://www.ideorg.org/OurMethod/FoodSecurity.aspx

appropriate micro irrigation technologies and/or adaptations."[m] Veronica not only could purchase IDE's treadle pump but she also had a range of assets (land holdings, farming knowledge, existing market participation, English literacy) that facilitated her participation in RPI. IDE project officers gave Veronica key information about high-value crops. Through RPI, IDE increases farmer income through *affordable* tools and *market* awareness. These differences suggest that Practical Action targets families living far below the poverty line while IDE focuses on families living at the poverty line. Many development professionals use assets as a proxy to indicate both poverty and vulnerability.[36-39]

	E.F. Schumacher *ITDG - Practical Action*	Paul Polak *IDE*
Project focus	Reducing vulnerability of marginalized populations	Leveraging assets already held by people living in poverty
Project approach	Grant-funded initiatives that transfer technology	Developing affordable tools and increasing market awareness

When engineers design projects to help alleviate poverty, the engineers need to understand how technical innovations operate in society. Engineers would do well to remember that better-off households often take risks with new technologies.[28, 40-44] Development professionals tend to underestimate the risks associated with technological adoption, focusing on large external risks such as political turmoil and famine. In their review of projects supported by the Gates Foundation, researchers report, "almost all projects explicitly or implicitly assuming that their stated objective and theory of change will have a presumed positive impact in reducing the risks farmers face" and "the investments required for technology adoption are not widely acknowledged as a potential increase in financial risk for the farmer."[44] Engineers need to remember that farmers encounter output, financial, and market risk when adopting new technologies. The nature of context-specific risk requires a systems approach capable of acknowledging local complexity.[45, 46] In the next section, I discuss how IDE and Practical Action attempt to bring change to communities.

The Legacy of Changing Communities

IDE and Practical Action conceptualize communities differently. Polak argued only functional markets can deliver sustainable development to people living in poverty because international charity efforts fail. Therefore, IDE models how specific markets operate in communities. IDE assumes customers will purchase various tools that improve a household's quality of life. Conversely, Schumacher highlighted gaps between urban and rural economies. Consequently, Practical Action considers how structural features create vulnerabilities in marginalized communities. Practical Action begins by looking at large-scale problems encountered within various communities. The conceptual differences between the approaches can lead to animosity between organizations.

IDE views people in poverty as consumers making rational business choices. Polak[3] exhorts designers to "talk to the people who have the problem and listen to what they say" and "continue to learn from your customers." Al Doerksen,[n] IDE's Chief Executive Director, and Roberts[o]

[m] IDE, Our Method, Gender http://www.ideorg.org/OurMethod/Gender.aspx
[n] Al Doerksen, "IDE has no beneficiaries" 29 June 2010 http://blog.ideorg.org/2010/06/29/ide-has-no-beneficiaries/
[o] Michael Roberts, "Success is in the toilet" 20 Jan 2011 http://blog.ideorg.org/2011/01/20/success-its-in-the-toilet/

agree that IDE should treat people living in poverty as customers, not as recipients of charity. Roberts[p] explains, "If I have to convince someone to purchase something, then my success is absolutely dependent on listening to them, understanding them, and responding to their highest priority needs." However, IDE's standard market-research methods[47] may limit the ability to listen to actual people. The methods center on smallholder farms as IDE[q] asserts, "more than 70 percent of the world's poorest people are small scale farmers." The focus on "smallholder farmers" hides the many diversities present among people living in poverty who rely on complex livelihood strategies.[36, 37, 48, 49] Additionally, IDE exhorts farmers to pursue off-season irrigation technologies. IDE appears to focus on customers who have a problem IDE wants to solve.

Where possible, IDE builds local manufacturing capacity. For instance, IDE Cambodia has been successful at stimulating latrine production businesses. The World Bank awarded IDE Cambodia with a sanitation grant to help Cambodia achieve development goals.[r] IDE designers partnered with a design consultant to create an integrated business model using specialized molds to streamline production processes. An aggressive marketing campaign led by IDE has sold over 10,000 latrines.[s] To expand farming production, IDE bundles training for smallholder farmers with their agricultural technologies. IDE's training focus extends to other contexts including to agricultural input sellers in Cambodia, vegetable farmers in Zambia,[t] coffee farmers in Honduras,[u] and well diggers in Ethiopia.[v] IDE provides knowledge-based support to participants leveraging their own assets to create viable businesses. However, relying on market forces to support entrepreneurship can limit participation to the better-off members in communities.[44]

Conversely, Practical Action addresses structures of poverty within marginalized communities with a current campaign to improve energy access. The campaign highlights vulnerabilities created when people lack reliable electricity such as unsafe living conditions[w] and poor educational attainment.[x] This rights-based campaign encourages people to "make the call" to secure "energy for all."[y] Additionally, Practical Action partners with existing local organizations to help specific communities secure energy access and meet other basic needs. For instance, Practical Action installed micro-hydropower and wind power schemes that provide electricity in isolated areas of Peru, Nepal, and Kenya. Through the Practical Answers database,[z] Practical Action provides direct technical support to communities across a wide range of technologies.

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[p] Michael Roberts, "Creating value at farm level" 24 Aug 2010 http://blog.ideorg.org/2010/08/24/creating-value-at-farm-level/

[q] IDE, Our Method, Water, www.ideorg.org/OurMethod/Water.aspx

[r] IDE's Sanitation Marketing Project Honored by World Toilet Organization, accessed at http://www.ide-cambodia.org/download/WTO_Hall_of_Fame_Press_Release.pdf

[s] IDE Shit Happens.Business Happens. Impact, accessed 9 February 2012 http://www.makingsanitationeasy.com/

[t] Veronica builds a house… with tomatoes, accessed 3 September 2011 http://www.ideorg.org/OurResults/SuccessStories/Veronica.aspx

[u] Micro-irrigation brings life changing alternatives to Hondurans, accessed 3 September 2011 http://www.ideorg.org/OurResults/SuccessStories/Honduras.aspx

[v] IDE, Our Results, Success Stories, Water and Work, accessed 3 September 2011 http://www.ideorg.org/OurResults/SuccessStories/WaterAndWork.aspx

[w] "Smoke: Killer in the Kitchen (Kenya)" uploaded 12 September 2008 http://www.youtube.com/watch?v=pDBOSA7rvjM

[x] "Access to Energy – Fighting Poverty" uploaded 20 August 2010 http://www.youtube.com/watch?v=2JHs2y9x-pw

[y] "Energy for Poverty Reduction" accessed 3 September 2011 www.practicalaction.org/energy

[z] Practical Answers, accessed 3 September 2011 http://practicalaction.org/practicalanswers/

Both IDE and Practical Action harness the energy of designers to solve problems that affect people living in poverty. Yet their different approaches can lead to animosity between the organizations. IDE is a newer charity that seeks to distance itself from Practical Action's approach. Specifically, Polak[aa] writes that the "appropriate technology movement died peacefully in its sleep" because designers failed to bring products to market. In calling for a design revolution "for the other 90 percent," Polak identifies a broad client base for engineers designing for poverty alleviation.[3, 4] The phrase originates in appropriate technologies and describes the world's poor as the 90% of the population that has "little or no access to most of the products and services many of us take for granted."[5] However, this phrase has no relevance in the international development community, which focuses on reducing poverty and vulnerability. While Practical Action does not ignore markets, "reducing vulnerability" is the first strategic aim while "making markets work for the poor" is the second of four strategic aims.[bb] The organization notes sociopolitical trends, such as exploitative migrant labor practices[cc] and failure of agricultural extension services to reach poor farmers, when working to achieve justice. According to Schumacher, "intermediate technologies" supported sustainable rural livelihoods as a part of a strategy to prevent worker exploitation.[1] Furthermore, Schumacher recognized the modern industrial system of the developed world needed to reform towards more sustainable practices. Practical Action's work on global policy continues to call for reforms in the developed world. Both organizations ask designers to develop technological solutions for people living in poverty. Therefore, both organizations can recreate power differentials between the designers and the receiving community.[41, 50]

	E.F. Schumacher *ITDG - Practical Action*	Paul Polak *IDE*
Status of marginalized communities	Contingent on historic experiences of injustice	Pool of rational consumers accessing new markets
Dominant orientation	Increase the voice of the marginalized	Empower consumers
Community engagement approach	Address key issues through both global political structures and targeted community projects	Expand capabilities of producers and consumers by leveraging IDE's technical expertise

When engineers work to alleviate poverty, the engineers should consider the limitations of their community engagement strategies. Technological innovations occur within a complex system. Simple linear models fail to capture the innovation dynamics.[45] Organizations fixated on one model of community engagement can miss learning opportunities.[51-53] Trade-offs exist between community participation and design expertise. However, organizations can explore different routes to participatory design through partnering with local designers[54] or developing workshop facilitation skills.[55] Engineers who cannot be based full-time in communities need to be especially thoughtful in how they engage communities. In the next section, I discuss how IDE and Practical Action educate various audiences about life in marginalized communities.

[aa] Paul Polak, "The Death of Appropriate Technology I: If You Can't Sell It, Don't Do It," 10 September 2010 http://blog.paulpolak.com/?p=376

[bb] Practical Action, Strategy, accessed 3 September 2011 http://practicalaction.org/strategy

[cc] Alexis Morcrette, "Engaging with the Elephant in the Room – Nepal's Exodus" 22 May 2011, http://practicalaction.org/blog/news/engaging-with-the-elephant-in-the-room-%E2%80%93-nepal%E2%80%99s-exodus/

The Legacy of Educating Others

The two organizations have different approaches to educating others. Polak has a living legacy still under construction as he speaks to diverse audiences and uses many forms of media to disseminate his message. He presents IDE as an idealized approach, emphasizing various successes. Schumacher provided a platform for people living around the world to converse about technology. ITDG launched a global publishing platform before the internet existed. Various manuals contained technical exemplars for development professionals working in the field. Today Practical Action engages many diverse audiences across a number of platforms.

Polak has an active presence on three websites: IDE, D-Rev, and his personal publicity site that advertises his book. Each site maintains a blog and employs a diverse social networking platform through Facebook, Twitter, and YouTube accounts. He consistently focuses his messages on market trial, consumer choice, profit, entrepreneurship, and effectiveness. When Polak advises technological start-ups, he encourages teams to talk to at least 25 customers about their needs before beginning any design.[dd] Designing businesses around high volume capitalizes on economies of scale. Business plans set target metrics to measure a solution's viability. Honoring people living in poverty as customers acknowledges a poor person's agency. Polak encourages businesses to expand markets toward the three billion people living in extreme poverty. He believes business growth comes from successfully engaging with poor consumers. Polak's extensive speaking circuit connects him to engineers, entrepreneurs, engineering students, and business students around the world.

Practical Action engages many diverse audiences. Not only does Practical Action provide technical support for communities, but also the charity engages in educational outreach about the global nature of technology. In particular, they call attention to how technologies create an ecosystem for livelihoods in both developed and developing countries. Because a considerable portion of people in poverty work in rural subsistence livelihoods attached to specific ecosystems, initiatives to recover local knowledge can play a key role in climate change adaptation. Practical Action conducts community projects all over the globe while designing technologies that facilitate community adaptation. Moreover, Practical Action continually educates policymakers on technical issues[ee] and also hosts competitions for school children to engage with sustainable development.[ff] Concerns about socially just forms of technology permeate the website. Therefore, Practical Action helps marginalized communities demand greater levels of technological justice. Working within marginalized communities can raise questions of how to best transfer local learning to global policy change.[24]

The two organizations devote considerable efforts to educating wide audiences. Engineering educators designing service-learning programs have opportunities to build from existing learning. Furthermore, several other organizations use different educational strategies. IDE

[dd] Paul Polak, "Death of Appropriate Technology II: How to Design for the Market" 17 September 2010. http://blog.paulpolak.com/?p=392.

[ee] Practical Action presents at international forums related to technological challenges of development. See http://practicalaction.org/events-29 for past participation.

[ff] Practical Action, STEM challenges and awards, accessed 3 September 2011 http://practicalaction.org/stem-challenges-and-awards

focuses principally in business communities while Practical Action engages in broader political activism. The table below highlights some of the differences between IDE and Practical Action.

	E.F. Schumacher *ITDG - Practical Action*	Paul Polak *IDE*
Vision	Creating equitable technological systems responsive to marginalized communities	Developing radically affordable technologies for emerging customer markets
Projects	Intentional strategies to engage chronically poor, vulnerable, or otherwise insecure households	Leveraging assets of people living in poverty to enable greater market participation both as producers and consumers
Community Models	Helping marginalized communities realize rights in local, regional, and global political systems	Catalyzing local businesses to serve customers living in poverty
Educational Approaches	Diverse platforms to engage many audiences (development practitioners, policy makers, general public, school children, etc)	Aggressive speaking and social media circuit highlighting IDE's successes

As the table shows, the two organizations differ considerably. I contend the differences in projects, community models, and educational approaches stem from the differences in vision. Schumacher's vision for more equitable technological systems inspired people to look at injustices currently present. Polak's vision for serving emerging customer markets stimulated conversations about design practices responsive to people living in poverty. Both approaches have value in an ever-changing world. However, engineering education researchers and engineering educators designing service-learning programs would benefit from more holistic frames to support student learning.[56]

Schumacher conceived of broad changes in technological systems at a global level. Practical Action employs strategies to partner with various community actors, realizing technical solutions along the way. Historically, ITDG developed a range of specific tools: windmills, solar cookers, crop driers, improved latrines, cook stoves, and water storage systems to name but a few. As a result, many people associate "appropriate technology" with tools incorporated with rural livelihoods.[2] Practical Action stresses pursuing globally relevant technological change. Consequently, Practical Action's work in specific community can fade into the background. Engineers attempting to alleviate poverty should consider technological systems in particular communities to ensure tools match strongly with context. Practical Action has started to use more holistic wellbeing frameworks to understand communities.[gg]

Polak rightly notes business plays an ever-increasing role in international development. Businesses pursue varied strategies to integrate marginal producers in global value chains,[57] harness the entrepreneurial energy found in marginalized communities to access new markets,[58] build public relations strategies around community improvement initiatives,[59] and pursue holistic

[gg] Simon Trace. "Sustainable well-being and inequality" 24 June 2010 http://practicalaction.org/blog/news/sustainable-well-being-and-inequality/

business models that include social and environmental concerns.[60] Various user-centered design movements call upon engineers to engage more effectively with end users.[54, 55, 61, 62] However, Polak overstates the distinctiveness of IDE's approach. Broadly, IDE's approach mirrors strongly to the Gates Foundation.[44] As a funding body, the Gates Foundation has much greater influence on how organizations design projects than one relatively small non-governmental organization. Additionally, Polak undercuts engineering design principles when he asserts that designers should follow a linear, 12-step process.[3] Designers following Polak's approach need to have extended presence in communities. Despite encouraging designers to have extended community engagement, Polak relies on one-time interviews to understand the highly dynamic contexts associated with living in poverty.[63] Emphasizing IDE's successes in a public arena can block internal organization learning.

Engineering educators designing service-learning programs encounter different constraints than non-governmental organizations. Working with students requires flexibility. Often, engineering students have limited engagement with their university's immediate community.[64] Additionally, students encounter many barriers to travel-based immersion programs.[65] Different students come to service-learning programs with varied goals and objectives. Accommodating student differences frequently requires creating a range of options. In the next section, I describe how engineering educators designing service-learning programs can incorporate the lessons gleaned from Schumacher's and Polak's legacies.

Practical Suggestions for Engineers Engaging with Marginalized Communities

Engineering educators can draw many lessons from the experiences of IDE and Practical Action. In this section, I highlight four lessons and place these lessons in a broader context. These four lessons include:

1. Build *long-standing* community partnerships,
2. Present students with *holistic* models of poverty,
3. Develop *informed* frameworks to determine innovation success, and
4. Create case studies rooted in *real* engineering initiatives in marginalized communities.

Engineering educators should critically reflect on their ability to make long-standing commitments to specific communities, taking care not to over-extend their reach. Building community partnerships takes time and commitment. Both IDE and Practical Action have a regular and long-standing presence in communities. Some innovative service-learning programs, such as MIT's D-Lab, pull together an enduring network of designers working in global communities. Other programs, such as Stanford's *Entrepreneurial Design for Extreme Affordability* course, develop technologies in partnership with field organizations like IDE. Michigan Tech has combined student experience and field organizations by organizing Master's programs around Peace Corps needs. Some service-learning programs, such as EPICS at Purdue University, focus on their own communities and work with non-traditional community partners. Additionally, universities network together to support global learning opportunities. Engineering educators have many options to create durable community partnerships.

Engineering educators should help students engage with the complex nature of poverty. The legacy of Schumacher and Polak speaks to the difficulties of using a single approach when alleviating poverty. Furthermore, the experience of IDE and Practical Action shows that

engineers often present their innovations as successes even when a design needs considerable improvements.[28, 33, 53] Engineers Without Borders-Canada[66] publishes "Failure Reports" to foster better understanding of the complex sociotechnical systems in marginalized communities. Engineering educators can use wellbeing frameworks[67] to define poverty more broadly as *the systemic failure to achieve wellbeing objectives* and to support student design learning.[56] The framework incorporates three primary design elements. First, it focuses on the expertise that the poor people themselves bring through their lived experiences rather than on external "expert" opinion ungrounded in the local context.[49] Second, it illuminates the community dynamics.[37] Third, active community participation facilitates participatory design and interaction with policy makers.[68] Practical Action has begun to shift towards using wellbeing frameworks.

Although Practical Action advocates using wellbeing frameworks, these frameworks from social sciences have not been strongly integrated with technical design. Engineering education researchers should use wellbeing frameworks when evaluating innovations to bridge knowledge gaps. These evaluations should consider how poverty, risk, and participation affect innovation systems. Interconnected global crises invite scholars to move beyond disciplinary silos, working to forge new collaborative institutions.[21, 69] While businesses and entrepreneurship play a key role in innovating for poverty reduction,[60, 65, 70, 71] engineers have a substantial role in shaping policy and supporting social movements.[72-75] Preparing engineers to design for wellbeing requires a broad view of a community's needs.[76, 77] Engineering education researchers should use the wellbeing frameworks to develop new innovation evaluation strategies.

Engineering educators should use the field experiences of organizations like IDE and Practical Action to design simulated learning experiences that incorporate concerns of marginalized communities. Traditional poverty alleviation design challenges focus on creating solutions to problems that differentially affect people living in poverty. Five of the fourteen "Grand Challenges"[78] of Engineering—make solar energy economical, provide access to clean water, restore and improve urban infrastructure, manage the nitrogen cycle, and advance personalized learning—have particular relevance to alleviating poverty. Innovative engineering educators have suggested that design for large-scale social issues brings together technical prototyping skills and professional engineering ethics.[9, 79, 80] Simulating design in marginalized communities allows educators to affirm pro-active choices around the social and technological trade-offs that minimize adverse effects.[6] Engineering educators can also invite students to critique innovation models of organizations like IDE and Practical Action. Through simulation, students can learn how to identify problems faced by a community.[44, 79] Furthermore, students can assess impacts of innovations in particular communities.[28] Students who develop and critique community engagement strategies in simulated learning environments may have greater opportunity to reflect on their own field experiences. Lastly, educators analyzing the field experiences of organizations such as IDE and Practical Action can analyze field experiences of their own global service-learning programs.

Conclusion

In this paper, I have explored the legacy of E.F. Schumacher and Paul Polak on engineering practices in developing countries. Both men founded organizations that have created technical solutions in developing countries for decades. Practical Action strives for socially just technological systems that highlight the interconnected nature of the developed and developing

world. The charity continues to raise awareness of how our current industrial systems exploit fossil fuels, test the tolerance limits of nature, and deny human dignity. IDE strives to include customers left out of traditional business models. The organization works to foster entrepreneurship and catalyze existing business activities.

The engineering practices of these two organizations raise questions of who benefits from the innovations. IDE's customers generally have considerably more assets than Practical Action's clients. Effectively engaging chronically poor, vulnerable or otherwise insecure households requires systematic approaches to enable participation. Practical Action partners with community organizations and other development organizations to work in some of the most marginalized communities. The two organizations use different approaches. IDE uses a market-led approach, developing products for smallholder farmers living at an income-based poverty line and catalyzing existing businesses that serve people living in poverty. Practical Action uses a sociopolitical approach, engaging with everything from international negotiations to village councils. Additionally, Practical Action develops a range of community level technologies to help marginalized communities achieve their development goals.

Engineers designing for poverty alleviation need to consider how innovations affect communities. Dynamics of innovation systems shift community structures. Design organizations use indicators that match their model of a community. If an organization sees a community as a consumer market, the organization tracks traditional business metrics such as profits and customer satisfaction. If an organization sees a community as an ecosystem, the organization tracks more holistic indicators. Furthermore, different community models can lead to animosity between approaches.

Engineering educators can use field experiences from organizations like IDE and Practical Action to engage students with pro-poor design. Defining poverty as *the systematic failure to achieve wellbeing objectives* provides a strong framework to compare different organizational approaches and to support student learning. When constructing global service-learning programs, engineering educators should explore long-term connections with specific communities and integrate pro-poor design into classroom learning. Engineering education researchers can support pro-poor design by developing innovation frameworks that incorporate poverty, vulnerability, and participation. In an increasingly connected world, training engineers in pro-poor innovation teaches engineering design that can promote responsible wellbeing on a global level.

1. Schumacher EF. *Small is Beautiful: A Study of Economics as if People Mattered*. London: Vintage; 1973.

2. Willoughby KW. *Technology Choice: A Critique of the Appropriate Technology Movement*. London: Intermediate Technology Publications; 1990.

3. Polak P. *Out of poverty: What works when traditional approaches fail*. San Francisco, CA: Berrett-Koehler; 2008.

4. *The Future Corporation*. Denver: TEDxMileHigh;2010.

5. Cooper-Hewitt. Design for the Other 90%. 2011; http://archive.cooperhewitt.org/other90/other90.cooperhewitt.org/. Accessed 27 December, 2011.

6. Baillie C. Engineers within a local and global society. *Synthesis Lectures on Engineering, Technology and Society*. 2006;2.

7. Bhatia S, Smith JL. Bridging the gap between engineering and the global world: A case study of the coconut (coir) fiber industry in Kerala, India. *Synthesis Lectures on Engineering, Technology and Society*. 2008;6.

8. Reader J. Globalization, Engineering, and Creativity. *Synthesis Lectures on Engineering, Technology and Society*. 2006;3.

9. Vanasupa L, Slivovsky L, Chen KC. Global challenges as inspirtation: A classrom strategy to foster social responsibility. *Science and Engineering Ethics*. 2006;12:373-380.

10. Riley D. Engineering and social justice. *Synthesis Lectures on Engineering, Technology and Society*. 2008;7.

11. National Academy of Engineering. *Changing the Conversation*. Washington, DC: National Academies Press; 2008.

12. Nye DE. *Technology matters: Questions to live with*. Cambridge, MA: MIT Press; 2006.

13. Eglash R. Appropriating technology: An introduction. In: Eglash R, ed. *Appropriating technology: vernacular science and social power*. Minneapolis: University of Minnesota; 2004.

14. Hughes TP. *Human-Built World: How to Think about Technology and Culture*. Chicago: University of Chicago Press; 2004.

15. Pfaffenberger B. Social Anthropology of Technology. *Annual Review of Anthropology*. 1992;21:491-516.

16. Schot J, de la Bruheze AA. The Mediated Design of Products, Consumption, and Consumers in the Twentieth Century. In: Oudshoorn N, Pinch T, eds. *How Users Matter: The Co-Construction of Users and Technology*. Cambridge, MA: MIT Press; 2003:229-246.

17. Pinch T, Bijker WE. The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science*. 1984;14(3):399-441.

18. Highmore B. A Sideboard Manifesto: Design Culture in an Artifical World. In: Highmore B, ed. *The Design Culture Reader (2009)*. London: Routledge; 2009:1-12.

19. Lindsay C. From the Shadows: Users as Designers, Producers, Marketers, Distributors, and Technical Support. In: Oudshoorn N, Pinch T, eds. *How Users Matter: The Co-Construction of Users and Technology*. Cambridge, MA: MIT Press; 2003:29-50.

20. Klein HK, Kleinman DL. The Social Construction of Technology: Structural Considerations. *Science, Technology, and Human Values*. 2002;27(1):28-52.

21. Woodhill J. Capacities for Institutional Innovation: A Complexity Perspective. *IDS Bulletin*. 2010;41(3):47-59.

22. Bartel CA, Garud R. The Role of Narratives in Sustaining Organizational Innovation. *Organization Science*. 2009;20(1):107-117.

23. Doolin B. Narratives of Change: Discourse, Technology and Organization. *Organization*. 2003;10(4):751-770.

24. Oswald K, Taylor P. A Learning Approach to Monitoring and Evaluation. *IDS Bulletin*. 2010;41(6):114-120.

25. Mautner G. Time to get wired: Using web-based corpora in critical discourse analysis. *Discourse and Society*. 2005;16(6):809-828.

26. Scollon R, LeVine P. Multimodal discourse analysis as the confluence of discourse and technology. In: Levine P, Scollon R, eds. *Discourse and technology: multimodal discourse analysis*. Washington DC: Georgetown University Press; 2004:1-6.

27. Coleman EG. Ethnographic Approaches to Digital Media. *Annual Review of Anthropology*. 2010;39:487-505.

28. Crewe E, Harrison E. *Whose development?: an ethnography of aid*. London: Zed Books; 1998.

29. Parker I. Introduction: varieties of discourse and analysis. In: Parker I, Bolton Discourse Network, eds. *Critical Textwork: An Introduction to Varieties of Discourse and Analysis*. Buckingham: Open University Press; 1999:1-12.

30. Gerring J, Thomas C. Internal Validity: Process Tracing. In: Gerring J, ed. *Case Study Research: Principles and Practices*. New York: Cambridge University Press; 2007.

31. Collier D. Understanding Process Tracing. *PS: Political Science and Politics*. 2011;44(4):823-830.

32. Goertz G, Mahoney J. A Tale of Two Cultures: Causal Mechanisms and Process Tracing. *Qualitative and Mixed Methods Newsletter*. 2010;8(2):24-30.

33. Chambers R. *Ideas for Development*. London: Earthscan; 2005.

34. Practical Action. *Practical Action: Our Story*. Rugby: Practical Action; 2010.

35. Practical Action. *People and Technology: Transforming Lives, Practical Action Group Strategy 2007-2012*. Rugby: Practical Action; 2007.
36. Ellis F. *Rural Livelihoods and Diversity in Developing Countries*. Oxford: Oxford University Press; 2000.
37. White S, Ellison M. Wellbeing, livelihoods and resources in social practice. In: Gough I, McGregor JA, eds. *Wellbeing in developing countries: From theory to research*. Cambridge: Cambridge University Press; 2007:157-175.
38. Chambers R. Editorial Introduction: Vulnerability, coping and policy. *IDS Bulletin*. 1989;20(2):1-7.
39. Moser CON. The Asset Vulnerability Framework: Reassessing Urban Poverty Reduction Strategies. *World Development*. 1998;26(1):1-19.
40. Rogers E. *Diffusion of innovations*. 5th ed. New York: Free Press; 2003.
41. Cornwall A. Beneficiary, consumer, citizen: Perspectives on participation for poverty reduction. *Sida Studies*. 2000;2.
42. Platteau J-P. Monitoring elite capture in community-driven development. *Development and Change*. 2004;35(2):223-246.
43. Sen A. *Choice of Techniques: An Aspect of the Theory of Planned Economic Development*. 3rd ed. Oxford: Basil Blackwell; 1972.
44. Sabates-Wheeler R, Butters S, Greeley M. Context-specific and Project-induced Risk: Designing Projects for Promoting Resilient Livelihoods. *IDS Bulletin*. 2010;41(6):96-104.
45. Millstone E, Van Zwanenberg P, Marshall F. Monitoring and Evaluating Agricultural Science and Technology Projects: Theories, Practices and Problems. *IDS Bulletin*. 2010;41(6):75-87.
46. Mowles C, Stacey R, Griffin D. What contribution can insights from the complexity sciences make to the theory and practice of development management? *Journal of International Development*. 2008;20(6):804-820.
47. International Development Enterprises. *Toolkit for Developing and Implementing Poverty Reduction through Irrigation and Smallholder Markets (PRISM) Programs*. Lakewood, CO: IDE;2007.
48. Collins D, Morduch J, Rutherford S, Ruthven O. *Portfolios of the Poor: How the World's Poor Live on $2 a Day*. Princeton, NJ: Princeton University Press; 2009.
49. Narayan D, Chambers R, Shah MK, Petesch P. *Voices of the Poor: Crying out for Change*. Vol 2. World Bank: Washington, DC; 2001.
50. Hickey S, Mohan G. Towards participation as transformation: critical themes and challenges. In: Hickey S, Mohan G, eds. *Participation: from tyranny to transformation? Exploring new approaches to participation in development*. London: Zed Books; 2004:3-24.
51. Chambers R. *Rural Development: Putting the Last First*. London: Longman; 1983.
52. Chambers R. *Whose Reality Counts? Putting the First Last*. Warwickshire, England: ITDG; 1997.
53. Chambers R. *Revolutions in Development Inquiry*. London: EarthScan; 2008.
54. Dearden A, Rizvi H. Participatory IT Design and Participatory Development: A comparative review. Paper presented at: Participatory Design Conference2008; Indiana University.
55. Luck R. Learning to talk to users in participatory design situations. *Design Studies*. 2007;28(3):217-242.
56. Nelson L. Scaffolding Undergraduate Engineering Education wtih the Wellbeing Framework. *American Society of Engineering Education Annual Conference and Exhbition*. Vol San Antonio, TX2012.
57. Humphrey J, Navas-Aleman L. Value chains, donor interventions and poverty reduction: A review of donor practice. *IDS Research Report*. 2010;2010(63).
58. Prahalad CK. *The fortune at the bottom of the pyramid: Eradicating poverty through profits*. Revised and Updated 5th Anniversary ed. Upper Saddle River, New Jersey: Pearson Education; 2009.
59. Christian Aid. *Behind the Mask: The Real Face of Corporate Social Responsibility*. London: Christian Aid; 2004.
60. Hart SL. *Capitalism at the Crossroads: Aligning Business, Earth, and Humanity*. Upper Saddle River, NJ: Wharton School Publishing; 2007.
61. Oudshoorn N, Pinch T, eds. *How Users Matter: The Co-Construction of Users and Technology*. Cambridge, MA: MIT Press; 2003.
62. Berdou E. *Mediating Voices and Communicating Realities: Using information crowdsourcing tools, open data initiatives and digital media to support and protect the vulnerable and marginalised*. Brighton2011.
63. McNeil Jr DG. An Entrepreneur Creating Chances at a Better Life. *New York Times*. 26 Sept 2011, 2011;Science.

64. VanderSteen J. *Humanitarian Engineering in the Engineering Curriculum*. Kingston, Canada: Civil Engineering, Queen's University 2008.

65. Mehta K, Brannon ML, Zappe S, Colledge T, Zhao Y. eplum Model of Student Engagement: Expanding non-travel based global awareness, multi-disciplinary teamwork and entrepreneurial mindset development. Paper presented at: ASEE Annual Conference and Exposition; 20-23 June, 2010; Louisville, KY.

66. Engineers Without Borders-Canada. Failure Reports. 2012; http://legacy.ewb.ca/en/whoweare/accountable/failure.html. Accessed 9 Mar, 2012.

67. Gough I, McGregor JA, eds. *Wellbeing in Developing Countries: From Theory to Research*. Cambridge: Cambridge University Press; 2007.

68. Wellbeing in Developing Countries. Country Reports: Bangladesh, Ethopia, Peru and Thailand. 2007; http://www.welldev.org.uk/research/country-reports.html. Accessed 24 April, 2011.

69. Hossain N. Beyond Silos: Complex Global Shocks and the New Challenges for Civil Society. *IDS Bulletin*. 2011;42(5):68-73.

70. Mehta K, Morais DB, Zhao Y, Brannon ML, Zappe S. Milking the Rhino - Innovative Solutions Showcase: Promoting Ethics Education, User-Centered Design and Social Entrepreneurship in the Global Context. Paper presented at: ASEE Annual Conference and Exposition; 26-29 June, 2011; Vancover, BC.

71. Yunus M. *Creating a World Without Poverty: Social Business and the Future of Capitalism*. New York: Public Affairs; 2007.

72. Edwards M. *Small change: Why business won't save the world*. San Francisco: Berrett-Koehler; 2008.

73. Berdegue JA. *Pro-poor Innovation Systems*. Rome: IFAD;2005.

74. Leach M, Scoones I. *The Slow Race: Making Technology Work for the Poor*. London: Demos; 2006.

75. Wilsdon J, Wynne B, Stilgoe J. *The Public Value of Science: Or How to Ensure that Science Really Matters*. London: Demos; 2005.

76. Gasper D. Conceptualising human needs and wellbeing. In: Gough I, McGregor JA, eds. *Wellbeing in developing countries: From theory to research*. Cambridge: Cambridge University Press; 2007:47-70.

77. White S. *Analyzing Wellbeing: A Framework for Development Practice*. Bath: University of Bath;2009.

78. National Academy of Engineering. Grand Challenges for Engineering. 2011; http://www.engineeringchallenges.org/. Accessed 16 April, 2011.

79. Kilgore D, Atman CJ, Yasuhara K, Barker T, Morozov A. Considering context: A study of first-year engineering students. *Journal of Engineering Education*. 2007;96(4):321-334.

80. Riley D. Employing liberative pedagogies in engineering education. *Journal of Women and Minorities in Science and Engineering*. 2003;9(2):137-158.