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How Service-Learning Can Enhance the Pedagogy and Culture of Engineering Programs at Institutions of Higher Education: A Review of the Literature

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Introduction

Many colleges and universities are actively renewing their commitment to service and to the transmission of knowledge for the public good. Students, faculty and administrators alike recognize the need to synthesize academic proficiency with responsible citizenry, in order to effectively participate in a diverse democracy.

As societal needs change, disciplines change as well. The field of engineering is no exception. A competitive, diverse, global market has forced vast changes in accreditation standards, which heavily impact the university and college engineering programs that tailor instruction to meet accreditor's requirements. In response to the evolving demands of industry, the field of engineering requires qualified candidates who will work collaboratively in diverse groups, excel at technical skills and can effectively communicate how their discipline impacts society. However, the current culture of engineering programs thrives on individualism, competition and male dominated discourse. Women and non-Asian minorities are severely underrepresented in the profession. In order to meet the great need for science and engineering graduates, engineering programs must adapt to find ways to recruit those populations, while also retraining and retaining its current populations (Thom, 2001).

Service-learning, with its emphasis on problem solving, experiential education and community engagement, is successfully being used within engineering programs to address the numerous recognized shortcomings in the pedagogy and the culture of engineering programs (Campus Compact, 1996). The result is the emergence of a new breed of engineers who work collaboratively with each other and community members to address community needs. Service-learning offers students an opportunity to take theoretical concepts learned inside the classroom and apply them outside in the community to solve real-world problems. The integration of

service-learning and engineering appeals uniquely to women and minorities, which not only creates a more diverse educational experience, but addresses the needs of a changing engineering industry. Though integrating service-learning into the analytical field of engineering does present challenges, successful models do exist and their positive outcomes are being documented in an increasing fashion.

The purpose of this paper is to conduct a significant review of the literature documenting and supporting how service-learning pedagogy can enhance a college-level engineering program. Topics will include (a) what is known about the influence of service-learning on students, (b) how engineering in the twenty-first century is a natural fit with service-learning and (c) how service-learning addresses engineering's leaky pipeline of enrollment and retention. Examples of successful models of engineering programs utilizing service-learning are discussed, as are barriers and further areas of research.

Service-Learning: What is Known About the Influence on Students

Lest we forget, the founders of land grant institutions saw education as a tool for building communities' capacity for cooperative action, and believed that the route to a civic society went through the universities (Damon, 1998; Gamson, 1997; Harkavy & Benson, 1998). Current research reveals that higher education is attempting to answer the urgent calls to return to its original mission of developing a well-informed, critically thinking, and civically engaged citizenry (Astin & Sax, 1998). Across campuses, there are mounting efforts to better prepare people to think about and act upon the public dimensions of educational experience. Research universities are reassessing the roles of their faculty and students in affirming their responsibility to promote public understanding and continue to benefit society by the transmission of

knowledge (Checkoway, 2001). In doing so, these institutions have created formal structures to recognize the important renewal of their civic missions (Wingspread Declaration, 1999).

If it is true that "the ultimate goal of schooling is to help students transfer what they have learned in school to everyday settings of home, community and workplace" (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000, p.73), then service-learning should have a history as old as education itself. Yet, service-learning is still evolving and has not yet settled into a generally accepted pedagogy. Because there still exists a great deal of experimentation with service-learning, it is next to impossible to have just one definition for all service-learning programs (National Service-Learning Clearinghouse, 2004).

Service-learning is a teaching and learning strategy that integrates "meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities" (www.servicelearning.org/welcome_to_service-learning/service-learning_is/index.php). The roots of this theory stem from American educational philosopher John Dewey, who stated that learning occurs best when one is actively involved in their own learning in purposeful reflective ways, but also when the learning has a distinct purpose (Dewey, 1916; Billig 2000). Using Dewey's statements as a foundation, Service-learning and experiential education are often synonymous. Kolb, one of the most influential theorists in learning theory, explains that experiential learning is most effective when a link is made between the knowledge and the experience, most commonly in the form of reflection (1984). As Kolb puts it, "learning is the process whereby knowledge is created through the transformation of experience." More recently, in translating the experiential education piece into pedagogy, four key components of service-learning have been identified as working together: the service component, the academic component, partnerships with

community organizations or members (which provide the structure for the service component), and analysis and reflection (Oakes, 2004).

Successful service-learning helps promote both intellectual and civic engagement by linking students' classroom work to real work problems and real world needs, without compromising discipline-specific objectives or academic rigor (Ropers-Huilman, Carwile, & Lima, 2005). Successful service-learning ensures that students merge theoretical concepts learned in the classroom with a practical aspect outside of the classroom, while reflecting on the value of their academic and service experience (Martin & Coles, 2000). This is especially valuable to undergraduates as higher order thinking skills grow out of direct experience; students are able to develop through active involvement and real-life experiences in workplaces and the community (Zlotkowski, 2001).

The missions of liberal arts colleges lend themselves to the goals of service-learning which include "further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility" (Bringle and Hatcher, 1996, p. 222). Universities are in a unique position to advance the common good as they have valuable resources (for example, students, faculty, staff, classrooms, libraries, technology, research expertise) that address many community needs (Bringle & Hatcher, 1996). Institutions of higher education also have a tradition of serving their communities by strengthening the economic development of the region, and contributing to the cultural life of the community (Ruch & Trani 1990-91, Muse 1990, Dore 1990). So congruous is service-learning with the mission of institutions of higher education, that faculty are increasingly integrating service-learning into courses (Campus Contact, 1998).

With the myriad of well-documented, positive outcomes associated with service-learning, institution administrations are sure to take notice. Service-learning participation impacts on many academic outcomes including demonstrated understanding, problem analysis, critical thinking, and cognitive development (Batchelder & Root, 1994; Eyler & Giles, 1999). Additionally, students engaged in service-learning report stronger faculty relationships (Astin & Sax, 1998; Eyler & Giles, 1999), are more likely to graduate (Astin & Sax, 1998), show greater satisfaction with their courses, report higher levels of learning about the academic field and the community than did students who did not participate in service-learning (Moely, McFarland, Miron, Mercer & Illustre, 2002). Service-learning students apply course material to new situations and real world problems (Eyler & Giles, 1999) and report stronger or much stronger changes during college in general knowledge, knowledge of a field or discipline and preparation for graduate or professional school (Astin & Sax 1998), than non service-learning participants. Of particular interest to administration officials is that undergraduate service participation is linked with an increased likelihood of becoming a donating alumnus of the undergrad college (Astin & Sax, 1998).

The real-world value of service engagement also translates into positive outcomes in student leadership, and personal development and understanding of others. In well-known studies, service-learning positively affected students interpersonal development and the ability to work well with others, and leadership and communication skills (Astin & Sax, 1998; Dalton & Petrie, 1997: Giles & Eyler, 1994; Vogelgesang & Astin, 2000; Moely, et al., 2002). Furthermore, service-learning showed reduced stereotypes and facilitated cultural and racial understanding (Astin & Sax, 1998; Astin, Sax, & Avalos, 1999; Driscoll, Holland, Gelmon, & Kerrigan, 1996; Eyler & Giles, 1999; Giles & Eyler, 1994; Vogelgesang & Astin, 2000) and

increased student commitment to civic involvement in the post-college years, regardless of their pre-college inclination to become involved in volunteer service work (Astin & Sax, 1998). With such documented positive outcomes for students, faculty and the community, it is no wonder that many in higher education have embraced service-learning.

Twenty-first Century Engineering and its Natural Fit with Service-Learning: Outreach, Experiential Education and the ABET Standards

Engineering is a discipline not often associated with community, despite the fact that one branch, civil engineering, has been called the "people's serving profession" (Oakes, 2004, p2). Unfortunately, the past and current culture of engineering, often associated with male dominated, solitary work environments, is no longer in synch with the current industry needs (Tsang, 2000). Today's engineers are being asked to do more than just make technical calculations; they must work on multidisciplinary teams in a multicultural environment, manage multiple projects, and compete in a highly diverse, global marketplace (Oakes, 2004). Teamwork, leadership and communication skills have become increasingly important to the scientific workplace (Hoekstra, Richmond, & Wadsworth, 1993; Kramer, 1996).

America's competitiveness and its technological leadership in the international marketplace are strongly challenged by both Western European nations and those in the Pacific Rim (Baum, 1990). Therefore, the United States has a critical need for a sufficient supply of engineer and scientists in order to remain competitive. At the same time, overall interest in engineering is declining in high school students (Baum, 1990). This decline has prompted a swell of K-12 outreach programs and secondary school pre-engineering courses (Oakes, 2004). Now, recruiters and admissions counselors are increasingly seeking women and minorities for engineering and other science programs not only to meet the state and national needs, but also to

provide creativity and new insight (Baum, 1990). These recruiters and admissions counselors are actively touting innovative curricular models that might appeal to the underrepresented minorities (URMs), such as models with an emphasis on active learning and 'softer skills' such as communication and group work (Tsang, 2000). Among these innovative curricular models is service-learning.

Research indicates the best opportunities for learning require a mix of pedagogical approaches: academic readings and materials, reflection activities, dialogue with others from different backgrounds, debriefing and analyzing community experiences and active involvement in personal and community change efforts (Chesler & Scalera, 2000, p.25). Service-learning can address all of those pedagogical components in engineering. Engineering programs with integrated service-learning components have a good future according to Miller (1994) who explains that service-learning programs that are integrated into the overall curriculum are more likely to enhance student development than those that are mandatory or voluntary. In other words, all disciplines are likely to benefit from the kinds of experiences made possible by service-learning (Zlotkowski, 2001).

While the positive academic, social and developmental outcomes associated with service-learning are well documented, it is also widely known that some disciplines, especially social and behavior sciences, seem to lend themselves more readily to service-learning initiatives (Zlotkowski, 2000; Moffat & Decker, 2000). Though engineering may seem to be an unusual discipline for service-learning pedagogy, Zlotkowski (2000) assures us that there is probably no discipline where service-learning curriculum cannot be implemented to strengthen student's abilities to become active learners and responsible citizens. In making the fit between engineering and service-learning, Zlotkowski (2000) states that the degree of fit for service-

learning pedagogy relies on how the specific discipline currently understands its broad social responsibility and how service-learning can enhance subject matter. Lending support to Zlotkowski, Martin and Haque (2001), call for a civic-minded class of engineers, citing the National Society of Professional Engineers codes of ethics that states, "Engineers shall at all times strive to serve the public interest." If traditional engineering programs are to embrace Martin and Haque's call, contemporary engineering must reorient itself to balance civic participation in a discipline traditionally grounded in the private sector. The link between engineering and service-learning is achievable as service-learning practitioners often report that service-learning assignments, with their concrete, real-world component, help beginning students see a discipline in a new light (Zlotkowski, 2000).

Engineering is uniquely positioned to integrate service-learning into its curriculum due to the emphasis on experiential learning, problem solving and collaborative grouping (Vaughn & Seifer, 2004). Those concepts, when combined with the design and production of a project that addresses a community need, benefit both the students and the community. Service-learning should be considered especially relevant within the field of engineering because frequently those receiving the services, are people not traditionally represented in the engineering field, namely women and minorities (Engineers That CAN!, 2005). This is especially relevant as some feel science, technology, engineering and mathematics (STEM) fields have failed to highlight the social value and relevance of the subject material, in exchange for securing corporate profits (Farrell, 2002). This disconnection between subject material and real-life application has been shown to negatively affect retention of women and minorities in engineering. In introducing service-learning into engineering programs, socially relevant projects will help build the bridge between those who typically serve and those who typically are served.

The Fit: Science & Outreach

When evaluating the fit between engineering and service-learning, an obvious starting point is the connection between the sciences and outreach. With the notion that research is to further the common good, the sciences have had their hand in service for years. Research on outreach and service-learning has shown that scientists feel a social responsibility to share their knowledge for the betterment of society (Hammond, 1994; Holland, 1999). In fact, a plethora of research shows that scientists are concerned with making a contribution to society (Abes, Jackson & Jones, 2002; Holland, 1999; Osguthorpe and Patterson, 1998). Wier's (1991) study noted that scientists wanted to encourage scientific knowledge, skills and interest in science, as well as help increase science literacy, correct misconceptions about science, and contribute to the positive value of publicly funded science. More specifically, service in engineering has been occurring for years in Civil Engineering. The service component of service-learning has been happening in the discipline, but without the reflection component (Tsang, 2000).

Graduate students in the sciences were the most likely to participate in outreach. Graduate students spent about five hours per month in outreach activities, typically giving scientific presentations, both on and off campus, or tutoring K-12 students (Campus Compact, 1998). Faculty members spent about half as much time as graduate students on outreach activities, giving presentations, both on and off campus, or acting as a resource for teachers. Abes et. al (2002) found that often faculty were successfully encouraged into service-learning via another faculty member, community member, or student.

The Fit: Engineering and Experiential Education

Engineering is no stranger to experiential education. Cooperative education, a learning program where students alternate periods of paid work in their major field, with academic class

time, remains a key, if not required, component of the many of engineering programs nationwide (Blair, Millea, & Hammer, 2004). Most programs require experiential time in laboratory settings or co-op programs, where a student works alternates between attending classes and gaining hands-on, paid, experience working at an outside company or agency. Cooperative (co-op) education has its merits in the engineering world, as one study proved that engineering majors who participated in coop ed earned higher cum grade point averages than non-co-op engineering majors (Blair, et al., 2004). In addition, engineering co-op majors earned more their non-co-op colleagues. The quantity of co-op experience was directly correlated with salary earnings (Blair, et al., 2004).

It can be said that engineers with cooperative educational experience are better poised for the active and community-learning environment of service-learning. Experiential education is "so important in building an engaged learning community because it puts the students' experiences, rather than the teachers, at the center of the knowledge construction" (Warren, 1998, p135). Because of real-world experiences, students are better able to understand why social change may be slow, complex and difficult, when they compare their theories and cultural assumptions to reality (Warren, 1998). And because of engineering's tradition of cooperative/experiential education, the link to service-learning merely lacks the guided and meaningful reflection.

The Fit: The Accreditation Board of Engineering and Technology Standards

A 1998 study of all of America's 1,635 engineering programs, at 337 Accreditation Board of Engineering and Technology (ABET) accredited institutions, revealed that over 70% did not require nor offer an ethics course for students (Eisman, 2000). In response to the engineering industry's demands for those well-versed in diversity, communication and

collaboration, ABET revamped their national standards in 2000. No longer was a strong technical background enough to meet the changing needs of the engineering society. ABET's new standards included competence in collaborative skills, working with diverse populations and an emphasis on ethics and social responsibility, and were designed to increase understanding of engineering solutions in a societal context, increase the ability to function on a multidisciplinary team (Zitomer & Johnson, 2003), and increase female and minority student interest in the engineering profession.

In part, the prior lack of emphasis on 'soft skills' was due to the rigidity of the requirements previously set by ABET (Farrell, 2002). However, with the standards implemented in 2000, service-learning has become a valuable pedagogy in helping students to meet the majority of learning outcomes identified by ABET. Ropers-Huilman, et al., (2005), believes that based on positive "experiences of students and educators in engineering, service-learning has the potential to help students meet the very important ABET criteria, largely because of its utilization of a hands-on approach that is both student centered and community centered" (p.156).

Ropers-Huilman, et al., (2005) cites an example of a service-learning based engineering class that addresses the new ABET standards of teamwork and communication, where the final project was the design and development of a school playground. This project emphasized larger concepts including design and evaluation methods, decision making, communication in design and how alternatives may affect the final product. With projects such as these, students put into practice their growing knowledge of the relationships between engineering design and a social context. As students were involved in designing a working solution to a real-world problem,

they indicated that the service-learning projects aided them in their ability to contextualize, formulate and solve engineering problems (Ropers-Huilman, et al., 2005).

Dewey (1938) proposed that we evaluate schooling by its success in creating and supplying the desire in the student for continual growth. However, the engineering curriculums often lack the means for creating 'continual growth' because the discipline is dependent upon traditional lectures, lab experiences, and artificial competition projects (Martin & Haque, 2001). Although United States engineering education is highly analytical and theoretical in nature (Derlin & McShannon, 2002), researchers conclude that engineering that utilizes service-learning has an opportunity to inspire students to think in new and dynamic ways (Martin and Haque, 2001). Some have indicated that both working with broader, scientific topics and having a direct impact on the "real world" was an invigorating and refreshing experience for scientists (Falk and Drayton, 1997; Wier, 1991). As a version of experiential education, service-learning naturally provides faculty with a variety of ways to engage students in the learning process. If utilized in engineering, not only is the learning experiential rather than lecture-based, but the education can be collaborative, emphasize teamwork, and require fewer lab benches or computer stations (Kramer, 1996), all while working towards ABET's standards.

Often, when service-learning is incorporated into engineering, the learning goes from textbook based, to problem based (Martin & Coles, 2000). The analysis is infused with real-life problems and creative solution making. Though research regarding service-learning and engineering has only developed recently, published examples of successful, service-learning experiences in mechanical, civil, chemical, environmental and engineering, are starting to emerge (Tsang, 2000). Students create water purification systems, public playgrounds, disabled accessibility ramps; they tutor and teach in public schools, and evaluate energy systems all for

the public good (Tsang, 2000). Furthermore, when students are actively engaged in researching, designing and building a product to address a community need, those involved see firsthand the "faces" of those who will benefit from their projects, and this adds an undeniable reason to fully understand the nature of the problem that creates the need (Oakes, 2004). Integrating service-learning into engineering courses offers students a chance to be inspired to cooperatively problem-solve in new ways, and reflect on the process, hopefully making them better engineers and better citizens (Moffat and Decker, 2000).

Service-learning Strengthens the Educational Pipeline: Appealing to Women & Minorities

Over the next ten years, the United States will need to train and educate an additional 1.9 million workers in the sciences (National Science Board, 2002). However, engineering has a leaky pipeline (Betz, 1990; Smith, 1983, Thom, 2001): Women and most racial minorities continue to be severely underrepresented in engineering, and the educational environment is often viewed as part of the problem (Seymour & Hewitt, 1997; Lent, Brown, & Larkin, 1987). Although the number of women and minority students in science and engineering has grown steadily, women and minorities are not entering nor completing engineering programs anywhere near the rate of non-minority men (Didion, 1997). This is especially crucial when considering that recent enrollment trends indicate that the underrepresented groups, minorities and women, will be essential in meeting the United States' demand for science workers (Chang, 2002). Though the enrollment and retention issues for women and minorities may be different, the fact remains that engineering programs are infamous for the pressure they exert on students (Greenfield, Holloway, & Remus, 1982). Women receive little support, and often face blatant discouragement when trying to succeed in nontraditional career fields such as engineering (Betz, 1990). Likewise, students of color in such programs experience predominantly White campuses

as inhospitable, alienating and insensitive and therefore as stressful and largely unsupportive (Rocha-Singh, 1990).

By the early 1990's, science educators had become concerned about the rate at which women and to a lesser extent, men, were abandoning STEM majors. Women were dropping out of these fields of study at a rate of 70%, compared to a male dropout rate of 58% in national samples (Seymour & Hewitt, 1997). A similar drop off continued in the workplace where women composed 33% of those earning degrees in science and engineering programs, but only 20% of professionals (Seymour & Hewitt, 1997). A decade later, the trend continued as women constituted 56.1% of all undergraduate students but only 22.6% of all engineering students; that same year women attained fewer than 20% of the engineering graduate degrees (Thom, 2001). The lack of women faculty role models does not help the picture become any brighter. As of 2002, the average engineering faculty is more than 95% male, and most of those professors were educated in a male-dominated environment (Farrell, 2002).

In considering the minority pipeline, researchers state that many students of color are less-certain that higher education will provide them the necessary skills for work (Teng, Morgan, & Anderson, 2001). Mendoza (1981), among others, gathered data supportive of the hypothesis that students of color, especially women, experience higher levels of stress and lower levels of support than do Euro-American students in engineering programs. This higher level of stress is often the result of sexism, racism, and differential treatment by faculty and fellow students coupled with a general lack of institutional support. This lack of support also results in lower occupational and self-efficacy expectations (Hackett, Betz, Casas et al., 1992). A notable exception to this would be HBCU's, where a lack of social and environmental barriers assists in

producing a disproportionate share of the bachelors degrees in science and engineering earned by black students (Lent, et al., 1987).

The problem of low graduation rates for underrepresented students in engineering has many causes. Almost 50% of those starting with a STEM major change majors within the first two years (Derlin & McShannon, 2002). Stereotypes of engineering fields often convey images of social isolation, competition and an inability or unwillingness to work with other people (Kramer, 1996; Kramer & Lehman, 1990). Individuals who work in technical careers but also enjoy working with people often switch their career focus (Giurleo, 2001).

For the URM's that do persist, the post-program picture is problematic given the relative status of these occupations in the economic system. The National Science Foundation (2000) found that URM's have significantly less prestige in science occupations. URM's were least-likely to be employed in a private-for-profit company, at a paltry average of 21%, in comparison to the 70% of Asian males and 69% of White males with engineering bachelors (Davis, 1996). Women and non-Asian minorities were most likely to be employed by the government or in an educational field, offering less income and less prestige (Davis, 1996).

The passage of the 1980 Science and Engineering Equal Opportunity Act hoped to address some of the issues causing the leaky pipeline in the sciences. This act states that "men and women, equally, of all racial and ethnic minorities, of all economic backgrounds should be encouraged to acquire skills and have equal opportunities to education, training and employment in science and technical fields" (Thom, 2001, p.22). Since then, dozens of women and minority professional organizations have established themselves on the engineering front, especially on college campuses. Studies of Women In Engineering (WIE) & Minority Engineering Programs (MEP) have shown that institutions with formal WIE and MEP programs tended to have higher

female and minority enrollment and grant more degrees to underrepresented minorities (Blalack & Daniels, 1999).

Global industries utilizing the services of engineers deliver a clear message: a diverse team of engineers will create a better solution than a team whose members think alike. With so few women and minorities entering this people-helping profession, the discipline is not accessing a major part of the population. And as women and minorities, especially female African American students are regularly overrepresented in service-learning classes (Chesler & Scalera, 2000), adding service-learning to an engineering program may plug a few holes in the pipeline. Service-learning becomes critical to addressing the leaky pipeline problems considering that teaching engineering in non-traditional formats has proven to be successful in bringing under-represented minorities and women into engineering (Kramer, 1996).

It has been stated that service-learning can be highly effective in attracting and retaining a diverse group of students. But it is also creates a different image of engineering by providing a social and/or community context which appeals to students that have a desire to help or work with others (Kondrick, 2003). Researchers Seymour and Hewitt (1997), found that women tend to enter their majors for personal and altruistic reasons, not for the instrumental and career-oriented reasons associated with men (see Rayman & Brett 1993). According to a Cooper Union Survey, the top reasons women go into engineering were the challenge of solving problems, a stable job, and an opportunity to help with society's problems (Baum, 1990).

Also, several studies suggest that women are more likely to participate in a broad range of service-learning activities than men (Eyler & Giles, 1999; Astin & Sax, 1998). Sax and Astin (1997) found that women may have a greater affinity for service work and preparation for service oriented careers because of their greater openness to non-traditional educational

programs. Adding a service-learning component to an engineering program would resonate strongly with females since they are more interested and accepting of a mandatory service requirement than men (Miller, 1994). This call to service may be a reason that traditional engineering programs do not appeal to women (Seymour, 2002). One of the primary reasons that women gave for switching into a non-STEM career was the prospect of greater social service in non-STEM fields such as education, medicine, and business (Seymour & Hewitt, 1997). This is evident in the helping sciences, especially nursing and health fields where women outnumber men eleven to one (Giurleo, 2001).

Integrating service-learning into engineering programs may also address pipeline issues that stem from a lack of role models. Both female graduate students and researchers were involved in outreach at a higher rate than their male counterparts (Surdyk & Diddams, 1999). Abes and colleagues (2002) also found a gender difference among faculty involved in service-learning, with more women than men participating in service-learning. In addition, community-service has deep, historical roots and plays an integral part of leadership training at many HBCUs, which produce a percentage, albeit small, of engineering faculty (Lent, et al., 1987).

One cannot address engineering's attrition rate without considering students' learning styles (Derlin & McShannon, 2002). Baxter-Magolda (1992) found that women tend to be more community oriented in their preferred learning style. Belenky, Clinchy, Goldberger, et. al (1986) proposed that women have a unique way of knowing, learning and interpreting the truth and constructing a scientific method may be innately discordant with the traditionally, male dominated programs (Kondrick, 2003). Female students are also more likely to be (Myers Briggs) extroverts than introverts, and somewhat more theoretical than results-oriented, and thus more likely to resemble the stereotypical profile of educational research scientists than engineers

(Kramer, 1996). Public perception of this notion explains the why women in STEM majors are more likely than men to be assigned teaching assistantships, where they interact with students, rather than research assistantships where they do hands on work with mentors and peers (Baum, 1990). Missing out on sought-after research or mentoring opportunities directly leads to isolation, a prime reason for the high dropout rate of underrepresented minority students in the first year of their engineering program (Baum, 1990).

Research by Derlin and McShannon (2002) found that a learning style that best suits minorities is cooperative learning, a style defined by learning with and from other students. Calderon (2003) notes that service-learning often provides opportunities for students of color to feel validated or supported, in large part from working with other students. Cohen (1995) describes how through service-learning, students of color gained an increased sense of identity and an increased ability to identify and articulate social injustices. Service-learning achieves this by presenting students with chances to interact with a diverse group of people and opportunities for developing problem solving skills, such as role-taking and conflict resolution, and an increased awareness of social institutions and power distributions (Moely, et al., 2002). Roose (1997), states that service-learning experiences increase retention and success of students of color. Formal strategies, such as service-learning, enhance opportunities for cooperative and hands-on learning with a social emphasis, and may be especially beneficial for non traditional students in engineering and pre-engineering programs (Kramer, 1996). Though the traditional lecture formats may work well for those who succeed by learning by themselves, mostly seniors and Caucasian engineering students, they "fail to provide same opportunities for more diverse students who have different learning styles and are less likely to be retained in engineering programs" (Derlin & McShannon, 2002, p.6).

The use of experiential activities is particularly effective in groups of people who have been typically expected to be passive in educational settings (Sadker & Sadker, 1994). Recent K-12 programs show that girls are drawn into math and science through active, cooperative learning settings, rather than competitive, individualistic approaches (Thom, 2001). In fact, cooperative education has proven academic benefits to women, as one study found that recent females who participated in an engineering program utilizing the cooperative education format had GPA's that were .143 higher than their male counterparts who had also participated in cooperative education (Blair, et al, 2004). In addition, in their 2005 study of URM's in service-learning , Ropers-Huilman, et. al, found that women and non-white participants generally assessed their learning outcomes to be greater than their white male counterparts.

The collaborative aspect of service-learning may assist with the leaky pipeline, as underrepresented minorities may find themselves more comfortable in an engineering program that incorporates community engagement and collaboration. Research indicates that African Americans, Native Americans & Latinos possess strong cultural values of group and community membership which may be at odds with the perceived levels of individualism and competition associated with the sciences (National Science Foundation, 2000). This concept is subtly echoed when considering that the most beneficial services of an MEP/WIE program are those that develop a sense of community, assist networking and develop leadership skills (Morrison & Williams, 1993). Women and minorities who are not prepared for such competition may switch to less competitive fields where they feel more comfortable (Giurleo, 2001; McIlwee 1983).

When looking at the competitive element of engineering programs, it is imperative to consider the traditional 'male' culture that pervades them. Programs that thrive on competition and 'weeding out' students (Tobias, 1990) can be perceived as overwhelmingly impersonal and

chilly for women, who according to Seymour (1992) became accustomed to high school faculty who regularly encouraged them. An engineering program integrated with service-learning, may offer more opportunities for mentoring relationships with faculty, as they assume the 'guide on the side' role. This need for supportive relationships with underrepresented minorities is supported by Lee (2002) who offers that if students do not encounter emotionally satisfying relationships they will imminently become disadvantaged in terms of achievement. Service-learning would assist in this effort, as it provides students opportunities to interact with different people, while providing opportunities for the development of social and problem solving skills, all the while helping to curb attrition.

Successful Models of Engineering Combined with Service-Learning

Successful implementation of service-learning can be found in many branches of engineering, including civil, mechanical, chemical, environmental and electrical (Oakes, 2004; Tsang, 2000). As of 2002, 10 of the top 16 undergraduate engineering programs, as ranked by *U.S. News and World Report,* currently implement service-learning (Oakes, 2004). Though relatively new, the power and promise of service-learning in engineering education is demonstrated through successful programs such as Engineering Projects in Community Service (EPICS) and Engineers Without Borders. These programs provide exceptional examples of integrated, interdisciplinary service-learning within engineering education (Vaughn and Seifer, 2004). Engineers Without Borders (and partner organization Engineers without Frontiers) promotes and facilitates the integration of international service projects into local engineering curricula. Student chapters of these organizations have been started at campuses across the country (Oakes, 2004). Service-learning projects carried out include improving rural water

supply and sanitation, creating local community resource management capabilities, and supporting multi-functional energy platforms in developing nations (Oakes, 2004).

EPICS brings multidisciplinary undergraduate design teams, first-year through seniors, into long-term partnerships with local community organizations and agencies. EPICS teams design, develop, deploy, and support technology- based solutions to the issues facing their community partners (Jamieson, 2002; Tsang, 2000). Started at Purdue University, but now found on 16 campuses, EPICS involves more than 20 disciplines in which undergraduates at all levels engage in long-term projects for the local community. Examples of projects include designing systems and structures for minimizing home construction and energy costs, designing and building therapeutic devices for children with disabilities, and designing wetland mitigation projects (Oakes, 2004).

In many other independent institutions, service-learning is being implemented in engineering first-year, senior or capstone courses and also into the interdisciplinary curriculum. An antithesis to the gigantic "weeder" classes, first-year service-learning classes are designed to introduce students to real-world problems in engineering at the start of their education. Examples of such programs include the University of South Alabama whose service-learning course in mechanical engineering pairs first-year students with a local school to develop mechanical educational aides for teachers to use in their curricula (Oakes, 2004). Case Western Reserve University has an optional, first-year course open to all students entering engineering, which pairs them with a faculty advisor and a community organization to repair historic structures or construct accessibility ramps or computer resource rooms (Oakes, 2004).

Senior design courses allow students to work on a project, alone or collaboratively, during the entire year. Often, these options are created to allow students to participate in projects

with specific community partners, to allow for multidisciplinary participation, or to provide continuity with a local community partner. Examples include Iowa State whose two-semester senior course allows seniors to design, build and install therapeutic devices for children with disabilities. A senior course at Purdue University combines agriculture and engineering to pair teams of students with local farmers with disabilities to design and produce assistive devices for farmers (Oakes, 2004).

Programs that incorporate co-curricular activities with engineering-based projects in the community can be found at University of Michigan's ProCEED (Program for Community Engagement in Engineering Design) program and the University of Massachusetts Lowell's International Engineering projects (Oakes, et. al, 2002). These courses may or may not be service-learning courses, but a supplemental experience, in line with the course constructs, integrate community service and reflection to enhance student learning.

Whether designing water purification systems in Peru (Duffy, 2000) or designing a new playground for a local school (Ropers-Huilman, et. al, 2005), such combinations of engineering and service-learning are making a difference in the lives of many. However, the most noteworthy differences may be the impact it has on engineering's enrollment. The changing face of engineering is reflected by Purdue University's EPICS program, where women participate at twice as often as men, and at the University of Wisconsin-Madison where their service-learning-enhanced engineering program sees women and minorities enrolling at twice the rate of the overall population (Oakes, 2004). To complement these service-learning integrated programs, the Anita Borg Institute, founded in 1997, is a collaborative network of ten colleges and universities that draws technical and non-technical women, and their supporters, into technology by bridging the connection between technology creation and social impact (Engineers That

CAN!, 2005). The widespread support for engineering and its focus on service and community change, will undoubtedly impact the future of engineering education.

Barriers and Further Research

Despite the existence of successful models of service-learning in engineering education, both researchers and practitioners note engineering's lag behind other disciplines in embracing this pedagogy (Oakes, 2004). The barriers to implementing any service-learning program are well documented and include the colleagues' lack of understanding about service-learning and its link to academic learning (Bringle & Hatcher, 1992), problems in adapting to the demands of a new pedagogy and demands on their time and energy (Hammond, 1994), the financial cost problems in funding and administrative support (Ward, 1998), and competition for class time (Astin & Sax, 1998).

In fact, implementation of service-learning throughout an engineering program raises several discipline-specific barriers. Perhaps the most obvious barrier might be a faculty and/or an administration possessing a traditional outlook about how engineering should be taught. Moffat and Decker (2000), state "engineering relies heavily upon linear, black and white thinking with little room for personal introspection and reflection" (p.31). Analysis and theory, the backbones of science education, are objective and allow little room for subjectivity, thus impacting concepts such as feelings and reflection. One of the primary challenges in engineering service-learning classes is to find models for reflection that address the needs of engineering courses (Tsang, 2000). Service-learning causes students to look at the gray areas, which are to be expected when addressing social issues. Although, the outlook may be shifting as several studies have recently indicated a need to modify the lack of social or reflective context present in engineering (Moffat and Decker, 2000).

While service-learning offers the opportunity to broaden an educational experience by engaging students in real-world issues, Herkert, (2000) found that scientists offered resistance to service-learning based courses. Herkert's research produced resistance in the form of poignant questions such as, if a science class is not truly based in science research theory, does it deserve to be counted towards a certificate? Should students be earning academic credit for courses in which a significant portion of the time is spent on "soft skills"? Zlotkowski (2000) advises that until the practitioners of service-learning and researchers reveal what service-learning can be expected to contribute to the specific disciplinary competencies, faculty will continue to believe that service-learning is an invalid pedagogy. Unless faculty can be persuaded to join this new concept of service and engineering, the prospects for academically and socially significant long-term institution-community partnerships seem far off.

Service-learning and engineering encounter a more logistical barrier when addressing community projects. Questions that require further study include, are students gaining valid technical experience on projects that are defined by another audience (outside customer) rather than by trained faculty (Jaimeson, 2002)? Is it practical for projects to be confined within the time limits of a semester, when community organizations have needs and deadlines that may not fit into an academic calendar (Anderson & Sungur, 1999)? Who will pay for the teaching assistants or building materials, or the specialized labs or meeting rooms (Martin & Haque, 2001)? Perhaps the most important question for the administration to consider is, who is liable for these projects, their success or their failures (Martin & Haque, 2001) and how will their effectiveness be assessed?

Conclusion

It is not just institutions of higher education that are recognizing their responsibility to enhance the public good. The field of engineering, with its foundations of problem solving and co-op elements, is in a unique position to revisit its civic mission. New ABET standards and recent findings show that the discipline is evolving in that direction. However, not all of this change is altruistic, as the need to sustain in a competitive and diverse marketplace is forcing engineering to revamp its accreditation standards to include 'soft skills.' These standards, emphasizing diversity, collaboration, communication and societal impact, have pointed out the flaws in the current engineering program culture and its reputation of individualism, competition, and isolation, rooted in male domination.

Engineering now needs to be marketed as a discipline of trained problem-solvers who can collaboratively enhance the quality of life (Baum, 1990). In order to achieve this, many programs are integrating service-learning within their curriculums. Service-learning, with its emphasis on cooperative learning and community engagement has become an effective pedagogy for engineering and real-world problem solving. Not only does service-learning assist students in meeting the new ABET standards, but the combination of service-learning with engineering strongly appeals to nontraditional engineering students, which addresses engineering's leaky pipeline issue. The result is engineering programs that retain students who learn by doing, and reflect on the 'softer skills' brought up by social issues and community needs. With the successful integration of service-learning and engineering, a more diverse group of students create real-world solutions to real-world problems and are better prepared for a future in an ever-evolving industry (Oakes, 2004). Service-learning is shaping the future of engineering programs by helping to create better engineers and better citizens. Though not all

scientists, practitioners and administrators embrace this combination, the ones who do are seeing

the positive academic and social outcomes associated with this curricular innovation.   .

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