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Measuring the Value Added from Service Learning in Project-Based Engineering Education*

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There has been a recent surge in project based service learning (PBSL) in engineering education. PBSL covers a spectrum of community-based projects both locally and internationally. While PBSL experiences can be embedded within courses, in many cases these activities are facilitated by non-academic organizations, such as Engineers Without Borders. These PBSL activities have undergone increasing levels of assessment, driven in part by the outcomes assessment requirements for engineering program accreditation in the U.S., but also because of apparent positive impacts to student participants. These studies indicate that the knowledge and skills gained by the students are at least on par with gains from traditional project-based learning (PBL). Attention is also increasingly being focused on the potential impacts of PBSL on student attitudes and identity. It is in these areas that differences in the influence of PBL versus PBSL appear more profound, yet small numbers of student participants in various programs and a lack of coordinated assessment efforts limits the statistical significance of these results. This paper highlights possible methods to determine the added value of service-based learning especially when coupled to project-based engineering education. Examples of evidence in the analysis of PBSL versus PBL in engineering are provided to further examine the state of this field. Considerable research will be needed to fully understand how service learning is impacting the education of engineers.

Keywords: project-based learning; service-learning; assessment; design; cultural competency; reflective essays

1. INTRODUCTION

THOUGH A PRECISE definition of project-based learning (PBL) may be elusive, it has been considered a model that meets the following five criteria: centrality, driving question, constructive investigations, autonomy, and realism [1]. That is, the project is central to the curriculum in which PBL is being practiced with the project based on an ill-defined problem that drive student inquiry for knowledge construction and project solutions. The last two elements of PBL (autonomy and realism) require the PBL to be student, not instructor, lead and that the project be couched within a real or authentic setting. Project based learning is a form of problem based learning [2], most often falling within the so-called *problem project* arena.

Service learning (SL) is defined by Bringle et al. [3] as: 'course-based, credit-bearing educational experience in which students (a) participate in an organized service activity that meets identified community needs and (b) reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.' Therefore, it is appropriate to view PBL and SL as having overlap, especially in how they are applied. Within engineering education, SL is generally conducted via PBL; thus, this approach is often colloquially referred to as *project-based service learning* (PBSL) by its practitioners [4]. In PBSL, the community is a full partner in the project and learning, subsequently outcomes from this educational model are more difficult to measure and often less predictable than traditional PBL. Despite the formal definitions of project-based and service learning, PBSL experiences have been integrated into courses (such as capstone design) yet often are conducted as extra-curricular activities; in fact many service project

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activities are facilitated by organizations external to the university. Improved understanding of students' learning outcomes from PBSL may facilitate better design of engineering education, and as such yield better engineering professionals.

This paper focuses on the assessment of PBL and PBSL with an emphasis on the value added from the inclusion of service to engineering education. This paper will provide a review of assessment methods, primarily from published literature, but also highlight assessment results obtained by the authors.

2. THEORIES BEHIND PBSL

Over the last twenty years, at least 200 different definitions of service learning have been published [5], the more recent of which have focused on service learning as a pedagogy. The distinguishing factor between service learning and community-service is that service learning is intentionally designed to meet academic course objectives. Additionally, the project-based element, connected to a community's need, provides the socio-cultural context, stimulating the process of collaborative problem solving. When the complementary pedagogies (project-based and service learning) merge, there is potential for student development on cognitive [6–10], social [11, 13–15], and moral [16–18] levels; three developmental processes that are tightly entwined, inseparable, and often trigger each other or occur simultaneously. The constructs are based on the theories of Dewey [6], Piaget [8–10], Kohlberg [16, 17], Vygotsky [13, 14], and Kolb [19]. An experience may spawn development on multiple levels, ultimately leading to maturation, heightened self-awareness, and greater complexity in cognitive thinking.

All theories agree that learning is a continuing, life-long endeavor that is vital to human development. Kolb suggests that this process represents a learning cycle in which experience translates into concepts that are used as guides towards new experiences. Jacoby [18] points out that there are three prevalent implications of Kolb's model that are central to service learning. First, the course must be structured with continual opportunities and challenges to enable students to move 'completely and frequently' through the learning cycle. Second, Kolb's model underscores how central and important reflection is to the learning cycle, and third, reflection must 'follow direct and concrete experience and precede abstract conceptualization and generalization' [19].

Kolb further identified strategies to increasing retention of knowledge in students. According to his theory, learning must begin with motivation, upon which theory, application, and analysis are founded. Engineers Without Borders, as are many other service programs, is completely voluntary; the motivation to help others and to learn is instilled within those who join [40]. The service aspect of PBSL initially motivates students to participate, but the cycle of overcoming problems and continual learning sustains them. Regardless of the construct, each suggests that PBSL should offer a rich learning environment for engineering students; one that fosters not only their cognitive development, but provides strong opportunities for social and moral development.

3. EXAMPLES OF PBSL IN ENGINEERING EDUCATION

In the U.S., most engineering programs require undergraduate students to complete a one or two semester capstone senior design course. This capstone design experience has become almost universal since the ABET (formerly the Accreditation Board for Engineering and Technology) Engineering Criteria 2000 (EC 2000) requirements for program accreditation [12]. This course is often considered a form of PBL, but the types of projects can vary tremendously. Some are fictitious 'example' projects; some are based on historical real projects, etc. The most common course model presented at the 2007 National Capstone Design Conference [21] was industry sponsored projects, with two of the three keynote speakers discussing this topic and 28 of 92 paper and poster abstracts highlighting industry sponsored projects. In contrast, only six papers' abstracts emphasized service learning projects; four of these included international PBSL projects including those conducted in association with EWB activities.

This difference between PBL and PBSL opportunities within capstone design is not surprising; numerous challenges with SL projects have been identified [4, 22, 23]:

- A need for the project purpose to align with program outcomes, a challenge when communities are equal partners in the process.
- A meaningful relationship with the community is imperative, particularly an on-going relationship to ensure that the community goals are served.
- A project planning phase before the beginning of the course is more critical to ensure a successful project.
- Site visits are very helpful so that students feel a connection; this can be difficult if class sizes are large or when working on international projects.
- A number of implementation challenges must be considered in project delivery including regulations, liability, local constraints, and sustainability.

Some infrastructure projects (e.g. civil or environmental engineering) for a community have a timeline to implementation longer than allowed in a single-course or academic year This complicates student involvement, reflection, and assessment in PBSL; an individual student may not witness the impacts of their work to the community and thereby undervalue the service learning opportunity. In addition, the strict regulatory requirements on these projects to be reviewed by a Professional Engineer (PE) and liability concerns can limit the use of PBSL in design projects. One solution to this problem is to conduct projects facilitated by Engineers Without Borders (EWB-USA), the International Center for Appropriate and Sustainable Technology (iCAST), or other non-profit organizations. Perhaps partly due to these curricular challenges with PBSL, EWB-USA has experienced tremendous popularity since its inception, growing from one to more than two hundred university chapters in six years [24].

Interestingly, this student interest in extracurricular PBSL coupled with participant testimonials of the outcomes from their involvement has created institutional momentum for integrating the approach within engineering curricula.

Research, sampling and feasibility studies are good targets for PBSL. PBSL can be incorporated into first-year project courses, core engineering science courses, and senior design courses [25–30]. Beyond formal courses, many students are active in conducting service projects for economically developing communities facilitated by university programs or extracurricular organizations. A student may work on the project for a number of semesters. Some students travel to partner communities, where they live and work on their projects for periods that typically range from one week to one month. Many community partners are often impoverished, rural areas in developing countries. This is a dramatically different setting than most students in developed countries have previously worked. So although the project to provide clean drinking water has the same basic goal as municipal drinking water projects in the student's home country, the constraints, criteria, and demands for a successful project are vastly different. To ensure the long-term success of a project the community must feel ownership of the project and be engaged in determining its path. The world is littered with examples of engineering projects that were implemented and then fell into disuse due to cultural inappropriateness, insufficient local expertise, equipment, and financial resources, lack of interest by the community, or poor design and construction. To engage in successful service projects, domestically or abroad, requires a range of skills, attitudes, and non-technical attentiveness beyond those encountered in the classroom-based projects that inspire most PBL efforts.

4. POTENTIAL OUTCOMES FROM PBSL

The impacts of PBSL on the knowledge, skills, attitudes, and identity of student participants are of great interest to students, faculty, and employers alike. A conceptualization of the breadth of outcomes affected is illustrated in Fig. 1. These outcomes will vary based on the learning goals for each PBSL opportunity and the context and intensity of the experience. Most of the research on PBSL uses a mixed methods approach of quantitative and qualitative research, and is typically

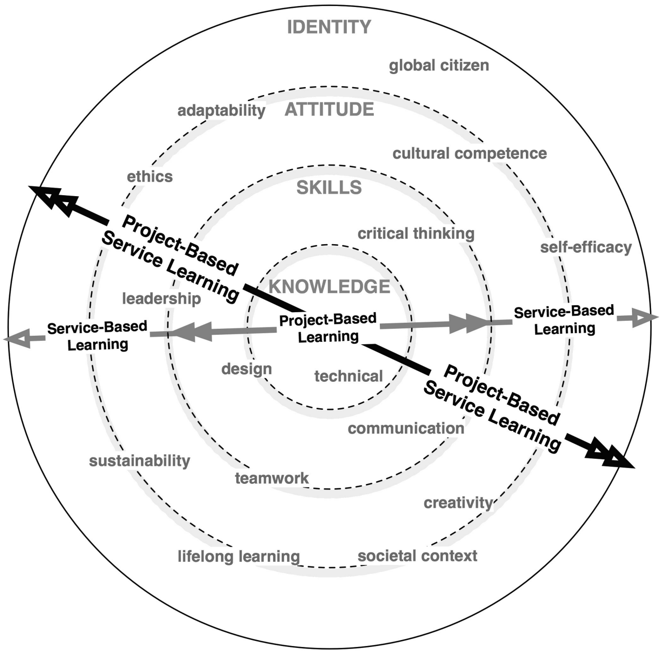

Fig. 1. A conceptual schematic of some noted student learning outcomes gained from involvement in project-based learning (mostly knowledge and skills), service-based learning (mostly attitude and identity), and project-based service learning (knowledge, skills, attitude, and identity).

summative. Little research on PBSL has combined formative and summative research methodology. Research conducted on course 'artifacts' that students would otherwise produce as course assignments, test responses, etc. may be the most effective. ABET has used this approach to accreditation in its site visits, where evaluators view examples of student work as direct evidence that various outcomes have been achieved. These artifacts provide direct evidence of what a student thinks, feels, and knows; however, the interpretations are often subjective. The development of rigorous rubrics and evaluative framework can standardize the assessment of student work. The scoring rubric for the Critical-thinking Assessment Test (CAT v. 5) is an excellent example of an interpretation guide for open-ended questions [32]. Unique to SL is the opportunity to evaluate reflective essays, journals, or diaries that are a required element of the course to facilitate student learning. Some design courses that are PBL rather than PBSL have also found the utility of the journaling process. Two key advantages of assessing student work that is submitted for course performance evaluation are that students do not feel that they are being 'studied' nor that they are burdened with additional activities.

Assessment of student knowledge and skill outcomes is now a fairly standard practice in U.S. engineering programs due to the accreditation requirements of ABET [12]. Many universities outside the U.S. are also basing their program reviews on the ABET model. ABET requires all engineering students regardless of their specific discipline to have universal 'A to K' knowledge and skills outcomes (see examples in Table 1). These encompass basic knowledge and skills that are fairly routine to assess and document across a curriculum. Curriculum-level assessment of knowledge often relies on standardized exams (such as the Fundamentals of Engineering exam). The ability to assess these outcomes from a single course is usually based on student performance demonstrated through exams, projects, and presentations; however, this generally reflects cumulative abilities rather than specific gains due to a single course as evaluated by pre- and post- assessments. Scoring rubrics created for various assignments can facilitate consistent evaluation of papers and projects for evidence of knowledge, skills, and attitudes. Research has generally found that PBSL is equally as effective or more so on teaching students knowledge and skills (i.e., cognitive development), with enhancements generally due to higher motivation associated with working on SL projects (i.e., social and moral development). Table 1 highlights student learning outcomes where PBSL has been shown to deliver superior results over PBL.

Some ABET elements are more difficult to rigorously measure, such as the ability to engage in life-long learning. Some U.S.-based engineering professional societies have also defined further outcomes goals for engineering students in specific disciplines, such as Civil Engineering [33] and Environmental Engineering [34] in their Body of Knowledge (BOK) documents. For example, the Civil Engineering BOK includes 'attitudes supportive of the professional practice of civil engineering' such as 'commitment, confidence, consideration of others, curiosity, entrepreneurship, fairness, high expectations, honesty, integrity, intuition, judgment, optimism, persistence, positiveness, respect, self esteem, sensitivity, thoughtfulness, thoroughness, and tolerance.' [33] At the Bachelor's level students are only required to explain these attitudes, although it is certainly desirable that they also model these attitudes. Items of this nature become much more challenging to demonstrate, leading to a greater complexity and proliferation of assessment instruments.

Faculty teaching these courses can directly evaluate student knowledge and skills via standard grading practices. Peer evaluations may also be an effective evaluation method. In addition, self-evaluation by the students on written 'Likert-style' rating surveys can be used to gather information on students' perceptions of gains in knowledge and skills. However, such self-perceptions often inaccurately reflect actual levels of abilities. Therefore, Likert-based surveys are better suited to measure attitude and identity.

In general, findings have shown that when properly applied, PBSL is an equally effective method to develop core technical competencies in engineering. PBSL also achieves a range of other, often unintended, benefits in an array of skills, attitude, and identity (refer to Fig. 1). A complete exploration of the methods that have been used to infer all of these outcomes from PBSL is beyond the scope of this paper. Therefore, we will focus attention on ethnographic methods that can be used to identify the range of potential outcomes, and more closely examine one outcome, cultural competency. Quantitative assessment instruments that have been developed to evaluate some of the other outcomes listed in Table 1 are also briefly described. It should be noted that developing assessment instruments that are fully validated and shown to be reliable is a challenging undertaking. As such, most engineering programs use instruments that are already available rather than developing their own. This may lead to a degree of compromise between what is desirable to measure and what is easy to measure with an existing instrument.

5. ASSESSMENT OUTCOMES EXAMPLES

5.1 Interpreting student reflective essays and journals using ethnographic methods

Although a vast array of quantitative instruments have been developed to measure a range of student attitudes and identity, these aspects are often best revealed from qualitative research methods. Given the richness of outcomes that are

Table 1. Improvements from PBSL in student knowledge, skills, attitudes, and identity as noted by past studies

Outcome	Assessment methods	PBSL advantages
Design a system or process within realistic constraints such as economic, environmental, social, political, ethical, health and safet . . . . [12].	Direct grading of project deliverables such as final report; Review student journals; Post-effort student interviews [26].	Greater complexity and range of constraints in PBSL settings deepen these abilities [27].
Cultural competency.	Intercultural Development Inventory, IDI [44]; Miville-Guzman Universality-Diversity Scale, MGUDS [45, 46]; Cross Cultural Adaptability Instrument, CCAI [47]; Global Perspective Inventory, GPI [48], BEVI [49]; Cultural Diversity Attitudes Scale, CDAS [50].	Developed as students work to understand the needs of communities with different cultural backgrounds from their own, both subtle or significant [41]; Students with significant international community service experience score higher on IDI [24]; Environmental engineering BOK requires students to 'function in a global system' which requires cultural competency [34].
Understand the impact of engineering solutions in a global and societal context [12].	Summative student self-assessment surveys.	Enhanced on PBSL projects by working directly with a community, hence these criteria are fundamental to the project [31, 37, 38, 57]; > 95% of students engaged in a PBSL capstone design experience self-reported high awareness of the social impact of engineering, significantly higher than non-SL project participants [86].
Understanding professional and ethical responsibility [12].	Commitment to social justice [63]; Defining Issues Test, DIT, of moral reasoning [64, 65]; Situational Intrinsic Motivation Scale [66]; Values survey [87].	Enhanced on PBSL projects, even if not a central theme of the project [4, 31, 38, 57].
Attitudes toward community service	Community Service Attitudes Scale, CSAS [58–61]; Social responsibility sub-scale of GPI [55].	Higher CSAS sub-scale scores for EWB participants and high for students in Engineering for Developing World course [61].
Self-efficacy, self-confidence, self-esteem.	Design self-efficacy instrument [67]; Learning self-efficacy instrument [68, 69]; Situational Intrinsic Motivation Scale [66]; Student Self-Determination Scale (SDSS) [71]; and the Student Thinking & Interacting Survey [62, 72].	Confidence in own abilities is enhanced, particularly as students achieve success and see the true benefits to a community [43].
Critical thinking / scientific reasoning.	California Critical Thinking Skills Test, CCTST [74]; Watson-Glaser Critical Thinking Appraisal, WGCTA [73]; Cornell Critical Thinking Test, CCTT [75]; Critical Thinking Assessment Test, CAT [32]; Collegiate Learning Assessment, CLA [77].	Critical thinking gains demonstrated for SL outside engineering [36, 76]; Not yet measured for PBSL in engineering education.
Engineering identity.	Engineering identity survey [78]; Ethno-graphic and qualitative methods [79, 80].	Redefine engineering as a helping profession.
Ability to communicate effectively [12].	Grading oral presentations and written reports; CLA to evaluate written communication skills [77].	Enhanced on PBSL projects due to students being required to communicate with community members who are often non-technical and across language and cultural differences [27, 38].
Function on multidisciplinary teams [12].	Summative self-assessment surveys; Peer evaluations; TIDEE Design Team Knowledge Assessment [81].	Greater stresses on PBSL projects may force students to learn better interaction skills; Many PBSL projects are more multidisciplinary, including non-engineers [38].
Recognize need for and ability to engage in lifelong learning [12].	Need for Cognition Scale to measure self-directed learning [70].	Because PBSL projects are often less structured and can go in many directions, students commonly forced to a just-in-time learning model.
Sustainability; Analyze systems of engineered works for sustainable performance.	Direct evaluation of design deliverables; Various knowledge, attitudes, and behavior surveys [82, 83].	Length of time working with communities on service learning projects directly influences usage and diversity of sustainability concepts [40]; Only evident in reflective essays from students in senior design who worked on PBSL projects, not among PBL students [27].
Leadership.	NRCS Leadership Assessment Instrument [84].	Students' have stronger understanding of leadership and skills to motivate others to achieve a common vision [37, 38, 42].
Creativity; *Creative Design.*	Creative Engineering Design Assessment, CEDA [85].	Open ended nature of PBSL projects with vast array of non-technical and technical constraints forces students to be creative to find best solutions for communities [39].

believed to be associated with PBSL, using a separate quantitative instrument to assess each aspect individually could easily make a student feel like a 'lab rat' and build resentment against these sometimes time-consuming approaches.

Service learning emphasizes the importance of self-reflection in order for students to get the most out of the experiences [3], which agrees with the theories of Dewey and Kolb. Therefore, to facilitate the learning experience SL activities should require students to complete reflective essays and/or journaling, and these artifacts are graded assignments in the course. These qualitative assessments can be coded for recurrent themes, transforming diverse responses into quantitative results. These responses can also help separate observed correlations from causative effects. For example, student engagement in PBSL can be voluntary (e.g., EWB-USA program) so particular care must be taken to avoid erroneously attributing student knowledge, skills, and attitude differences to the PBSL experience itself versus a bias in the population of students that gravitate to these opportunities. Evolution in student attitudes over time will be measurable if multiple reflective essays and/or frequent journaling is required.

The senior Environmental Engineering capstone design course at the University of Colorado—Boulder (CU) requires all students to write a single reflective essay at the end of the semester. Although such reflections are an important aspect of SL, not all students in the course participate in PBSL and thus student comments indicate that they feel excessive journaling or essay writing is a burden. Students have yet to be convinced that reflection activities are an important part of the learning process and have been resistant to increased assignments of this nature. Despite this limitation, results from the single reflective essay have been informative. Example results from a coding exercise conducted on thirty-three open-ended essays are summarized in Table 2.

Sustainability was only an emergent theme in the essays of students who had participated in the PBSL projects. Similarly, a study at Michigan Tech reports that a major educational impact from involvement in PBSL with developing communities is greater mastery of sustainability concepts [29]. The length of the PBSL program influenced the 'richness' and 'balance' of the sustainability language content of the student written project reports [30].

A similar approach was used in the study by McCormick and Swan [38], who examined the daily journals of six students who lived for a month in Ecuador as part of an EWB project to develop and build a water collection and treatment system for the community and conduct water sampling for another community. In overcoming challenges, the students showed evidence that they learned about leadership and teamwork, bonded with community members, gained confidence in applying engineering technology, and began to perceive their ability to positively impact others. These journal results confirmed results that were evident in pre- and post- trip surveys. The mixed methods approach provides the greatest richness of data and can be used to determine specific aspects of the PBSL experience that lead to growth in cultural awareness, intercultural competency, and similar characteristics.

5.2 Skills and attitudes related to cultural differences

Cultural competency is an important skill in an increasingly global environment where teams are likely composed of people from varying cultural backgrounds and projects may be conducted with communities with different cultural norms. A number of failures of global development projects related to water and sanitation projects can be directly attributed to the engineers' lack of understanding of the culture of the people that the projects were serving. Therefore, PBSL activities hope to impact students' knowledge, skills, and attitudes of different cultures, as well as their sense of identity when immersed in different cultures. These cultures can be attributed to socio-economic status, religion, or national differences. Cultural competency requires self-awareness, awareness of differences in cultures, and reflection on the implications of these differences. Cultural competency is closely related to intercultural competence, cultural sensibility, cultural sensitivity, cultural

Table 2. Most common emergent themes from environmental engineering capstone design essays among all students, those visiting a project site, those engaged in service learning projects (PBSL) and those engaged in standard projects (non-SL). Totals do not sum due to multiple groupings for some students (e.g. visited site and worked on a service learning project)

Theme discussed in student essay	Total #/% students	% site visitors (n = 15)	% service learning projects (n = 26)	% non-SL projects (n = 7)
Real world experience	30/91	97	92	86
Data: poor, rich, assumptions	26/79	87	85	57
Communication importance	25/76	87	79	71
Serve community	21/64	60	65	50
Importance of non-technical aspects	20/61	47	58	71
Relationship with real project/community motivating	16/48	53	56	29
Disparity of stakeholder goals	15/45	53	46	43
Team work with other students	12/36	43	42	14
No one right answer to design problems	11/33	40	37	14

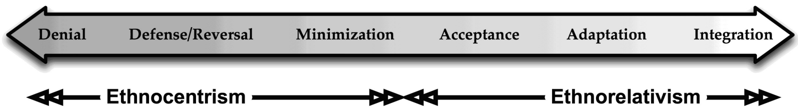

Fig. 2. Spectrum of intercultural sensitivity adapted from Bennett [see 44]. PBSL opportunities aim to achieve intercultural sensitivity development by providing experiences that shift participants further to the right within the spectrum.

humility or intercultural development. Regardless of its precise name, this skill is important when engineers work with stakeholders from diverse backgrounds. The development of technology that is appropriate for a given community requires considerations far beyond technical constraints. As shown in Table 1, a variety of written assessment instruments have been created to evaluate these skills and attitudes, although they have mostly been applied in contexts outside engineering education.

The Intercultural Development Inventory (IDI) measures progression of worldview orientations toward cultural differences [44]. The basic model is shown in Fig. 2 and was developed from Bennett's [51, 52] developmental model of intercultural sensitivity. The five main dimensions are: (1) denial/defense; (2) reversal (a type of defense); (3) minimization; (4) acceptance/ adaptation, and (5) integration. The IDI measures intercultural competency using the first four dimensions only through a written survey comprised of 10 demographic questions, 50 statements to which participants respond on a 7-point Likert scale, and a statement of experiences. The IDI has been used in a variety of studies [44, 53].

Michigan Tech uses the IDI in association with evaluation of students and faculty in several programs within their D80 Center (www.d80.mtu.edu). At Michigan Tech the average PBSL student thinks they are accepting of cultural differences but actually they are between reversal and minimization of cultural differences. Evidence also suggests that international experience typically results in further development: students with no experience are more likely to be ethnocentric, while students with substantial experience are more likely to be ethnorelative [24]. Conversely, there is no evidence to suggest that PBL experiences have any impact on intercultural competence as measured by pre-PBSL involvement IDI scores. Predictably, students appear to change markedly only through opportunities outside the classroom. This is a level of understanding that cannot be derived from simpler instruments such as the MGUDS-S survey described below. A discussion of the results with individuals can help clarify their personal biases and determine ways to progress. Thus the instrument can serve both assessment and educational functions.

The evaluation instrument used at the University of Colorado is the Miville-Guzman Universality-Diversity Scale (MGUDS-S) [45, 46]. The instrument was developed to evaluate universal-diverse orientation (UDO). UDO is 'an attitude toward all other persons which is inclusive yet differentiating in that similarities and differences are both recognized and accepted' [45]. Sub-scales of the instrument assess cognitive, behavioral, and affective components: relativistic appreciation of self and others, seeking diversity of contact with others, and a sense of connection with larger society or humanity, respectively. At CU the MGUDS-S survey has been used in the civil and environmental engineering senior design classes [41]; results are summarized in Table 3. Response rates are generally very high since the instrument is so quick and easy. This study has found that UDO is higher for the students who participated in PBSL in the environmental engineering course than the students in the PBL-based civil engineering course. However, based on surveys of first-year students, it appears that environmental engineering students initially have a greater UDO, and only minimal 'growth' is evident between the first year and senior students. The diversity of contact sub-scale showed the greatest increase between the environmental engineering first year and senior students (data not shown).

Even more important in determining cultural competency as measured by the MGUDS-S survey appears to be voluntary participation in EWB; in the 2009 environmental engineering senior design course, the five EWB participants had an average overall UDO of 15.0 ± 0.9 compared to 13.1 ± 1.3 for the non-EWB participants. Because longitudinal evaluations of the same students pre- and post-EWB participation has not been measured, it is unclear if students

Table 3. Universal-Diverse Orientation (UDO) scores (average ± standard deviation) out of a maximum of 15 for engineering students from different majors at the beginning and end of the curriculum

Student major	UDO score of first year students	Senior course format	UDO score at end of senior design courses
Civil Engineering	12.7 ± 1.7	PBL	12.1 ± 1.2
Environmental Engineering	13.5 ± 1.5	PBSL	13.9 ± 1.8
General Engineering	12.3 ± 1.8	N/A	N/A

with higher UDO are attracted to participate in EWB and/or if their participation increases their UDO. Among the first-year students, too few have participated in EWB or international service activities to determine a difference; 4 of 43 in 2008 that reported this activity have an overall UDO of 14.1 compared to the overall average for this group of 13.5.

The problem with the MGUDS-S survey is that it cannot show what factors contributed to the measured UDO, other than through correlations to basic demographic information asked at the beginning of the survey. It may be more powerful to link the measured UDO to qualitative information. However, at this time the MGUDS-S survey has been administered anonymously and there is no way to match responses with the reflective essays in the senior design or first year engineering courses. Therefore, the instrument simply gives a numerical score, and there is generally no feedback to individuals on how they scored. Other examples of cultural competency assessment in engineering include a course-specific evaluation instrument used by Downey et al. [56] in association with an Engineering Cultures course.

6. CONCLUSIONS

PBL and PBSL are both effective pedagogies to achieve a broad array of core knowledge and skills that are critical for engineers. The added value of service learning projects in engineering education appears to be largely in achieving higher cognitive levels in some skills and in attitudes and identity outcomes (i.e., social and moral development). The richness of PBSL experiences frequently imparts professional and personal development beyond conventional learning objectives, yet which are nonetheless important for engineers. A wide variety of quantitative and qualitative assessment methods are available to help demonstrate these outcomes. Most of the quantitative written survey instruments that have been fully validated were not developed specifically for engineering education or PBSL contexts; this may limit their utility and/or require that validation of the instruments using data from engineering students be conducted. In order to determine the impacts of a PBSL course or experience these instruments should generally be administered in a pre/post format. However, without qualitative information it is difficult to determine the attributes of the PBSL experience that led to the changes. Qualitative information can be coded to yield quantitative results. To the extent possible, it is generally preferable to use course assignments to assess outcomes, as they are direct measures and do not require extra work for the students. For PBSL, reflective essays and journals should be required assignments to facilitate learning, and these provide rich information to reveal attitudes and identity. To adapt the use of course assignments for assessment, scoring rubrics should be established to minimize subjective judgment and bias. The authors strongly encourage the rigorous assessment of PBSL courses and extracurricular activities, thereby building the body of knowledge on best design and management practices for these educational experiences in order to build desired knowledge, skills, attitudes, and identity outcomes for our students and their communities.

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REFERENCES

1. J. W. Thomas, A Review of Research on Project-Based Learning, The Autodesk Foundation, San Rafael, CA, http://www.bobpearlman.org/BestPractices/PBL_Research.pdf, 46 pp., 2000.
2. E. de Graff and A. Kolmos, Characteristics of problem-based learning, *International Journal of Engineering Education*, **19**(5), 657–662.
3. R. G. Bringle, M. A. Phillips and M. Hudson, *The Measure of Service Learning: Research Scales to Assess Student Experiences*, 227 pp. American Psychological Association, Washington, DC, 2004.
4. A. R. Bielefeldt, K. Paterson and C. Swan, The State of Project-Based Service Learning in Engineering Education. NSF Report. http://www.d80.mtu.edu/PBSL. 25 pp., 2009.
5. Furco, Issues of Definition and Program Diversity in the Study of Service-Learning, In: *Studying Service-Learning*, S. H. Billig (ed.), pp. 13–34, Lawrence Erlbaum Associates, Publishers, Mahway, NJ, 2003.
6. J. Dewey, *Democracy and Education*, Free Press, New York, 1916.
7. J. Dewey, *Experience and Education*, Collier Books, New York, 1938.
8. J. Piaget, *The development of thought: Equilibration of cognitive structures*, Viking Press, New York, 1977.
9. L. Harrisberger, R. Heydinger, J. Seeley and M. Talburtt, *Experiential Learning in Engineering Education, Project Report*, American Society for Engineering Education, Washington, D.C., 1976.
10. R. Siegler, Piaget's Theory on Development, In: *Children's Thinking,* pp. 21–61, Prentice Hall, Englewood Cliffs, NJ, 1991.
11. E. Duckworth, Either we're too early and they can't learn it, or we're too late and they know it already: The dilemma of 'applying Piaget', in: *The having of wonderful ideas and other essays on teaching and learning*, 2nd. edition, pp. 31–49, Teachers College Press, New York, 1996.

12. ABET. *Criteria for Accrediting Engineering Programs Effective for Evaluations During the 2009–2010 Accreditation Cycle,* 21 pp., ABET Engineering Accreditation Commission, 2008. www.abet.org.
13. L. S. Vygotsky, Interaction between learning and development, in: L. S. Vygotsky, *Mind and Society: The development of higher psychological processes,* pp. 70–91, Harvard University Press, Cambridge, MA., 1978.
14. L. S. Vygotsky, The development of scientific concepts in childhood, in L. S. Vygotsky, *Thought and Language* (pp. 146–209). MIT Press, Cambridge, MA, 1986.
15. R. M. Felder and R. Brent, The intellectual development of science and engineering students. 2. Teaching to Promote Growth, *Journal of Engineering Education*, **93**(4), 2004, pp. 279–291.
16. R. DeVries and L. Kohlberg, *Constructivist early education: Overview and comparison with other programs*. Washington, D.C: National Association for the Education of Young Children, 1987.
17. L. Kohlberg, The cognitive development approach to moral education, *Phi Delta Kappan,* **56**, 1975, pp. 670–677.
18. B. Jaccoby and Associates, *Service-learning in Higher Education*, Jossey-Boss, San Francisco, CA, 1997.
19. D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*. Prentice Hall, Englewood Cliffs, N.J., 1984.
20. L. Kohlberg and Colleagues, *Child psychology and childhood education*. Longman, White Plains, N.Y., 1987.
21. J. Zable (chair), *National Capstone Design Course Conference Proceedings,* Sponsored by the ASEE and NSF, June 13–15, University of Colorado—Boulder, CO. 91 pp., 2007. http://www.capstoneconf.org/
22. J. H. Hanson, R. J. Houghtalen, J. Houghtalen, Z. Johnson, M. Lovell and M. Van Houten, Our first experience with international senior design projects—lessons learned, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings,* June 18–21, Chicago, IL., 2006
23. J. Aidoo, J. Hanson, K. Sutterer, R. Joughtalen and S. Ahiamadi, International senior design projects—more lessons learned, *National Capstone Design Course Conference Proceedings*, Paper 11810. Boulder, CO., 2007.
24. K. G. Paterson, Development for the Poorest 80%: Learning by serving those in need. Engineering Dean's Institute, Boston, March, 2009.
25. M. J. Piket-May, J. P. Avery and L. E. Carlson, 1st year engineering projects: a multidisciplinary, hands-on introduction to engineering through a community/university collaboration in assistive technology, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Session 3253, 1995, pp. 2363–2365.
26. C. Swan, T. Rachell and K. Sakaguchi, Community-based, service learning approach to teaching site remediation design, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, June, St. Louis, MO., 2000.
27. A. R. Bielefeldt, Environmental engineering service learning projects for developing communities, *National Capstone Design Course Conference Proceedings*, Paper 12183, June 10–12, University of Colorado—Boulder, CO, 2007.
28. A. R. Bielefeldt, Challenges and rewards of on-campus projects in capstone design, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Design in Engineering Education Division. Portland, OR., June 2005.
29. V. J. Fuchs. *International engineering education assessed with the sustainable futures model*, MS Thesis, Michigan Technological University, Houghton, MI, USA, 60 pp., 2007.
30. K. G. Paterson, Development for the other 80%: assessing program outcomes. *Global Colloquium on Engineering Education Proceedings,* Cape Town, South Africa, 2008.
31. M. S. Pritchard and E. Tsang, Service learning: A positive approach to teaching engineering ethics and social impact of technology, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Session 3630, 2000.
32. B. Stein, A. Haynes, M. Redding, T. Ennis and M. Cecil. Assessing critical thinking in STEM and beyond, in M. Iskander (ed.) *Innovations in E-Learning, Instruction Technology, Assessment, and Engineering Education,* pp. 79–82, Springer, 2007.
33. American Society for Civil Engineering (ASCE), *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future*, 2nd edition, 191 pp., ASCE, 2008. www.asce.org.
34. American Academy of Environmental Engineers (AAEE), *Environmental Engineering Body of Knowledge*. 91 pp., AAEE, 2009. www.cecs.ucf.edu/bok/publications.htm
35. National Academy of Engineering (NAE). *The Engineer of 2020: Visions of Engineering in the New Century,* 118 pp., National Academies Press, 2004.
36. A. Sedlak, M. O. Doheny, N. Panthofer and E. Anaya, Critical thinking in students' service-learning experiences, *College Teaching,* **51**(3), 2003, pp. 99–103.
37. J. Duffy, D. Kazmer, L. Barrington, J. Ting, C. Barry, X. Zhang, D. Clark and A. Rux, Service-learning integrated into existing core courses throughout a college of engineering, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Paper 2007–2639, 34 pp., 2007.
38. M. McCormick, C. Swan and D. Matson, Reading between the lines: evaluating self-assessments of skills acquired during an international service-learning projects, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Pittsburgh, PA, June, 2008.
39. D. Christy and M. Lima, Developing creativity and multidisciplinary approaches in teaching engineering problem solving, *International Journal of Engineering Education*, **23**(4), 2007, pp. 636–644.
40. K. G. Paterson and V. J. Fuchs, Development for the other 80%: engineering hope, *Journal for Australasian Engineering Education*, **14**(1), 2008, pp. 1–12.

41. A. R. Bielefeldt, Cultural competency assessment, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings,* Paper 2008–2313, June 23–25, Pittsburgh, PA, 2008.
42. J. Ejiwale and D. Posey, Enhancing leadership skills through service learning, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings,* Paper 2008–2457, 2008.
43. S. Gokhale and M. O'Dea, Effectiveness of community service in enhancing student learning and development, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, St. Louis, MO, June, Session 1621, 2000.
44. M. R. Hammer, M. J. Bennett and R. Wiseman, Measuring intercultural sensitivity: The intercultural development inventory, *International Journal of Intercultural Relations,* **27**(4), 2003, pp. 421–443.
45. M. L. Miville, P. Holloway, C. Gelso, R. Pannu, W. Liu, P. Touradji and J. Fuertes, Appreciating similarities and valuing differences: The Miville-Guzman universality-diversity scale, *Journal of Counseling Psychology,* **46**(3), 1999, pp. 291–307.
46. J. N Fuertes, M. L. Miville, J. J. Mohr, W. E. Sedlacek and D. Gretchen, Factor structure and short form of the Miville-Guzman universality-diversity scale, *Measurement & Evaluation in Counseling and Development,* **33**(3), 2000, pp. 157–170.
47. Kelley and J. Meyers, *The Cross-Cultural Adaptability Inventory*, National Computer Systems, Minneapolis, MN, 1995.
48. L. A. Braskamp, Developing global citizens, *Journal of College & Character*, September 2008. http://www.collegevalues.org/pdfs/Braskampdeveloping.pdf
49. C. Shealy, A model and method for 'making' a combined-integrate psychologist: Equilintegration (EI) theory and the Beliefs, Events, and Values Inventory (BEVI), *Journal of Clinical Psychology,* **60**(10), 2004, pp. 1065–1090.
50. N. Dogra and N. Karnik, First-year medical students' attitudes toward diversity and its teaching: an investigation at one U.S. medical school, *Academic Medicine,* **78**(11), 2003, pp. 1191–200.
51. M. J. Bennett, Towards ethnorelativism: A developmental model of intercultural sensitivity, in R. M. Paige (ed.), *Cross-cultural orientation: New conceptualizations and applications,* pp. 27–70, University Press of America, New York, 1986.
52. M. J. Bennett, Towards ethnorelativism: A developmental model of intercultural sensitivity, in R. M. Paige (ed.), *Education for the intercultural experience,* pp. 21–71, Intercultural Press, Yarmouth, ME, 1993.
53. O. Durocher, Teaching sensitivity to cultural difference in the first-year foreign language classroom, *Foreign Language Annals,* **40**(1), 2007, pp. 143–160.
54. S. L. Davis and S. J. Finney, A factor analytic study of the cross-cultural adaptability inventory, *Educational & Psychological Measurement*, **66**(2), 2006, pp. 318–330.
55. L. Braskamp and K. C. Merrill, Global Perspective Inventory (GPI) (2009). https://gpi.central.edu/index.cfm
56. L Downey, J. C. Lucena, B. M. Moskal, R. Parkhurst, T. Bigley, C. Hays, B. K. Jesiek, L. Kelly, J. Miller, S. Ruff, J. L. Lehr and A. Nichols-Belo, The globally competent engineer: Working effectively with people who define problems differently, *Journal of Engineering Education,* **95**(2), 2006, pp. 107–122.
57. J. Duffy, W. Moeller, D. Kazmer, V. Crespo, L. Barrington, C. Barry and C. West, Service-learning projects in core undergraduate engineering courses, *International Journal for Service Learning in Engineering,* **3**(2), 2008, pp. 18–41.
58. H. Shiarella and A. M. McCarthy, Development and construct validity of scores on the community service attitudes scale, *Educational and Psychological Measurement,* **60**(2), 2000, pp. 286–300.
59. H. Shiarella, A. M. McCarthy and M. L. Tucker, Refinement of a community service attitude scale, *Annual Meeting of the Southwest Educational Research Association Proceedings,* 35 pp., 1999.
60. E. H. Bauer, B. Moskal, J. Gosink, J. Lucena and D. Munoz, Faculty and students attitudes toward community service: A comparative analysis, *ASEE Journal of Engineering Education,* **96**(2), 2007, pp. 129–140.
61. A. R. Bielefeldt, B. Amadei and R. Sandekian, Community service attitudes of engineering students engaged in service learning projects, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings,* Paper 2008–2430, June 23–25, Pittsburgh, PA, 2008.
62. S. H. Schwartz, Normative influences on altruism, in L. Berkowitz (ed.), *Advances in experimental social psychology,* **10**, pp. 221–279, Academic Press, New York, 1977.
63. T. F. Nelson Laird, M. E. Engberg and S. Hurtado, Modeling accentuation effects: Enrolling in a diversity course and the importance of social action engagement, *The Journal of Higher Education*, **76**(4), 2005, pp. 448–476.
64. J. Rest, *Development in Judging Moral Issues*. University of Minnesota Press. ISBN 0816608911, 1979.
65. J. Rest, D. Narvaez, M. Bebeau and S. Thoma, DIT-2: Devising and testing a new instrument of moral judgment, *Journal of Educational Psychology,* **91**(4), 1999, pp. 644–659.
66. R. Guay, J. Vallerand and C. Blanchard, On the assessment of situational intrinsic and extrinsic motivation: The Situational Motivation Scale (SIMS), *Motivation and Emotion*, **24**(3), pp. 175–213.
67. D. Bergin, S. K. Khanna and J. Lynch, Infusing design into the G7-12 curriculum—two example cases, *International Journal of Engineering Education*, **23**(1), 2007, pp. 43–49.
68. Bandura, Guide for Constructing Self-Efficacy Scales in Self-Efficacy Beliefs of Adolescents. F. Pajares and T. Urdan. Information Age Publishing. Greenwich CT., 2006. http://www.des.emory.edu/mfp/self-efficacy.html
69. B. J. Zimmerman, A. Kitsantas and M. Campillo, Cuestionario de Intereses Profesionales Revisado, *Evaluar*, 5 (octubre), 2005, pp. 17–20.
70. J. T. Cacioppo, R. E. Petty, J. A. Feinstein and W. B. G. Jarvis, Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition, *Psychological Bulletin*, **119**(2), 1996, pp. 197–253.

71. S. Field and A. Hoffman, Development of a model for self determination, *Career Development for Exceptional Individuals*, **17**, 1994, pp. 159–169.
72. M. E. Engberg and M. J. Mayhew, The Influence of first-year 'success' courses on student learning and democratic outcomes, *Journal of College Student Development,* **48**(3), 2007, pp. 241–258.
73. G. Watson and E. M. Glaser, *Watson-Glaser Critical Thinking Appraisal*, The Psychological Corporation, 555 Academic Court, San Antonio, TX, 1980.
74. P. Facione, *The California Critical thinking Skills Test: College Level,* The California Academic Press, 1990. http://www.insightassessment.com/test-cctst.html
75. R. H. Ennis and J. Millman. *Cornell Critical Thinking Test*. Critical Thinking Press and Software (formerly Midwest Publications), Pacific Grove, CA, 1985. http://www.criticalthinking.com/series/055/index_c.html
76. A. W. Astin, L. J. Vogelgesang, E. K. Ikeda and J. A. Yee, *How Service Learning Affects Students,* Higher Education Research Institute, University of California—Los Angeles, 2000.
77. S. Klein, R. Benjamin, R. Shavelson and R. Bolus. The collegiate learning assessment—Facts and fantasies, *Evaluation Review,* **31**(5), 2007, pp. 415–439.
78. D. Chachra, D. Kilgore, H. Loshbaugh, J. McCain and H. Chen. Being and becoming: Gender and identity formation of engineering students, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings,* Paper 2008–960, 2008.
79. T. K. Beam, O. Pierrakos, J. Constantz, A. Johri and R. Anderson, Preliminary findings on freshmen engineering students' professional identity: implications for recruitment and retention, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Paper 2009–993, 2009.
80. D. P. Dannels, Learning to be professional: Technical classroom discourse, practice, and professional identity construction, *Journal of Business and Technical Communication*, **14**(1), 2000, pp. 5–37.
81. D. C. Davis, Transferable Integrated Design Engineering Education (TIDEE), Mid Program Assessment: A Three-Part Assessment of Team Based Design for Entering Juniors. (2001). http://www/cea/wsu.edu/TIDEE
82. B. J. M. de Vries and A. C. Petersen, Conceptualizing sustainable development: An assessment methodology connecting values, knowledge, worldviews and scenarios, *Ecological Economics,* **68**, 2009, pp. 1006–1019.
83. A. C. Michalos, H. Creech, C. McDonald and P. M. H. Kahlke, Measuring knowledge, attitudes and behaviours towards sustainable development: two exploratory studies. *International Institute for Sustainable Development*, 2009. http://www.iisd.org/pdf/2009/measuring_knowledge_sd.pdf
84. Natural Resources Conservation Service. Leadership Assessment Instrument. http://www.ssi.nrcs.usda.gov/publications/2_Tech_Reports/T024_Leadership_Assessment.html
85. C. Charyton, R. J. Jagacinski and J. A. Merrill, CEDA: A research instrument for creative engineering design assessment, *Psychology of Aesthetics, Creativity, and the Arts*, **2**(2), 2008, pp. 147–154.
86. G. Kremer and D. Burnette, Using performance reviews in capstone design courses for development and assessment of professional skills, *American Society for Engineering Education (ASEE) Conference and Exposition Proceedings*, Paper 2008–1041, in presentation slides (2008). http://www.ent.ohiou.edu/~me470/Resources/ASEE2008_ presentation_PerformanceReviews.ppt
87. C. Baillie, G. Catalano, Y. Nahar and E. Feinblatt. Engineering values: an approach to explore values in education and practice, *Research in Engineering Education Symposium*, Queensland, Australia, 2009. http://rees2009.pbworks.com/f/rees2009_submission_3.pdf

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