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Going is Not Knowing: Challenges in Creating Intercultural Engineers

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Abstract

The last twenty years has witnessed a surge in the growth of community engagement programs for engineering students in the United States. Coupled to the enthusiasm of the Millennial Generation, many of these efforts have an international community development focus where engineering teams work with community members on small-scale infrastructure. One expressed motivation for such programs is the transformative experience and mindset-shift many participants report upon return from their time abroad. Industry has been quick to endorse such opportunities as necessary in creating the "global engineer", a professional adept and effective in a dynamic interconnected work world. This paper explores these perceptions through an objective measure of intercultural awareness, the Intercultural Development Inventory (IDI). The IDI is a cross-culturally valid and reliable method to assess intercultural competence development, and is suggestive of a learner's proficiency at working with others who view the world differently. This paper will report the results of two large engineering student cohorts: 149 students at a mid-sized technical university in the US, and a 120 student sample from five different institutions across the US. The former group is a mix of singular sampling, but all students were involved in one or more optional sustainable development programs. The five institution group was tested annually for three years, and had a range of service experiences (from none to many). The technical university cohort averaged an IDI developmental orientation score of 90.7, a Minimization mindset (identifies commonalities between cultures); whereas the five institution group averaged an 81.9 which is in the transition from a Polarization mindset (identifies that one culture is superior, often through an "us versus them" perspective). The latter dataset had no statistically significant differences among institutional IDI averages, although one institution showed significant decreases in IDI amongst their students. A majority of engineering students report increased levels of engagement with time in their studies. However, an examination of the longitudinal dataset reveals slightly more than half the participants had decreasing IDI scores over three years of engineering education; engineering community engagement experiences (and engineering education in general) seem to have little impact on the intercultural mindsets of engineering students on average, although about 20% of individuals experienced substantial shifts of more than 10%/yr. This study suggests considerable attention to the design and implementation of service experiences will be needed to yield the intercultural engineer.

1. Introduction

Our world is increasingly interconnected economically, socially, politically, environmentally — as is the work landscape. Whether working with international colleagues, for an international employer, with international clients, or simply with people experiencing a different upbringing, today’s engineers will encounter a multicultural reality more diverse than past generations. While academia may have been able to talk about such global shifts, competitive industry has moved to capitalize on them. As a consequence, requests abound for a modern engineering education to include significant attention to this new global context through accreditation modernization[1], industry preparedness[2-4], and academic revolutions[5]. Coupled with these calls for attention to the

international dimensions of engineering are those for a renaissance in engineering education pedagogy to deal with persistent issues of effectiveness[6-7] and inclusion[8], among others. Community engagement has been suggested as a solution to both challenges[9]. In their typical engineering incarnation, these service experiences are project-based, multi-stakeholder efforts, producing a rich learning opportunity for many complex subjects. These experiences resonate with many engineering students, offering a more resonant engineering identity and perceived fit with the profession[10]. There is no better indicator of the thirst for such professional connection than the dramatic emergence of Engineers Without Borders - USA chapters across American universities; nearly 200 institutions started a chapter within the first decade of the organization's launch in 2005[11]. While EWB is a prime national example, many engineering programs across the country pre-dated EWB in developing their own robust community engagement offerings. Today it is unusual to find a college of engineering in the U.S. without several such options for students, both locally and abroad.

The prospects for a new generation of engineers capable of effective work across cultures seems bright; yet the rapid emergence of these offerings (and the position of many outside the required curriculum) has outpaced our ability to assess potential learning outcomes for participating students. This paper aims to contribute evidence regarding the engagement and cultural agility of engineering students, providing data-driven insight and reflection in the process.

Our research effort focuses on two specific working hypotheses:

> **H1:** Service-oriented international experiences attract engineering students with an intercultural mindset
>
> **H2:** Participation in service-oriented experiences will lead to elevated intercultural proficiency for engineering students

These research hypotheses will be tested in the following ways:

> • Comparison of intercultural assessment data among participants in several programs at one university (H1)
>
> • Longitudinal evaluation of intercultural assessment and service involvement data at five different institutions (H2)

2. Methodology

The Intercultural Development Inventory (IDI) is a cross- culturally valid and reliable method to assess intercultural competence development[12], and is the focus of this paper's investigation. The IDI is suggestive of the student's proficiency at working with others who view the world differently. The IDI yields quantitative results, placing the student along a spectrum of intercultural sensitivity (see Figure 1) from ethnocentrism to ethnorelativism in stages of denial,

defense, reversal, minimization, acceptance, and adaptation[13]. The IDI is available as an online 50-question tool, but requires a qualified administrator for use (the lead author has been trained on its use). Each assessment costs $11 per participant ($10 during some of the years of data collection reported below). While the IDI produces several scales, the developmental orientation (DO) results will primarily be used throughout this work as an indicator of the actual intercultural proficiency of the participants. The DO score is suggestive of that individual's primary orientation toward cultural differences and commonalities as assessed by the IDI, and provides a position to examine and plan personal development. The perceived orientation (PO) is a second score produced by the IDI and suggestive of where the individual would place themselves along Bennett's intercultural development continuum.

Bennett's model (which the IDI represents numerically) is founded on two broad categories of cultural understanding: monocultural mindsets are those that avoid cultural differences, whereas intercultural mindsets can be defined as seeking cultural differences. Within each category lie a spectrum of intercultural stages: *denial* (refuting that there are different cultural interpretations through avoidance and disinterest in others), *polarization* (an "us-them" mindset that can result in either a defense of their own culture, or a reversal of cultural loyalty by embracing the others' culture), *minimization* (focus on similarities and universal features of cultures), *acceptance* (appreciation of cultural similarities and differences), and *adaptation* (ability to shift behaviorally and cognitively as culturally appropriate).

Figure 1. Developmental model of intercultural sensitivity as represented by the Intercultural Development Inventory. Numbers indicate IDI scores for developmental orientation (DO) and perceived orientation (PO) scales.

2.1 Technical University Investigation

The first portion of this work focuses on an exploration of intercultural proficiency of nearly 150 students engaged in one of several sustainable development programs at a mid-sized public technical university (MPuT) sometime over the years 2009 to 2013. Two-thirds of the students at this university pursue a degree in a STEM field, with the vast majority in engineering. Two-thirds of those students are undergraduate. The students in this study self-selected into one of the optional sustainability programs and took the IDI as part of a larger effort to better understand the student body choosing these programs. While some students in this pool did take the IDI

later in their studies (for other reasons), the lack of completeness prohibits a "pre/post" evaluation. Instead the following two data explorations were performed:

1. Evaluation of the basic statistics for the IDI results (PO, DO, and the "gap" or difference between PO and DO) for the whole student cohort
2. Evaluation of basic statistics for the IDI results broken out by program

A presentation of this data and findings (in Section 3.1) provides a baseline snapshot for a sizable pool of engineering students in programs with various levels of community engagement. Students in the pool were seeking degrees in a range of engineering disciplines, however nearly three-quarters were pursuing environmental or civil engineering degrees. No investigation of programmatic "culture" (either from their degree department, nor sustainable development program) is attempted with this pool due to the lack of adequate post data.

2.2. Five Institution Investigation

The second portion of this work presents preliminary investigation of a longitudinal study following 120 engineering students for three years. In brief, the research effort consists of a longitudinal study performed at four target institutions: a small private research-focused (SPrR), a large public research-focused (LPuR), a large public undergraduate-focused (LPuU) and the above mid-sized public technical university (MPuT). A fifth "institution" (EWB) was comprised of students at more than 12 universities (not including the above four) actively involved in Engineers Without Borders. These institutions are diverse in size, type, mission, and student socio-economic conditions. In addition to their academic cultural differences, these institutions have experience with the integration of student engagement in their curricular and extracurricular activities, as well as the presence of strong faculty champions. These faculty were important in early recruitment and local implementation of the assessment program within their institutions.

Student participants were drawn from volunteer pools (via targeted announcements on each campus), with students placed into appropriate pools based on class level (either first-year or junior year candidates at start) and their expressed intentions for the next three years (i.e. to participate in service activities/studies, or not). Student demographics, as well as some basic feedback their community engagement involvement level were collected. These participants also were asked to take the IDI annually. While a mixed-methods approach was used to allow triangulation of results, this paper only presents IDI results; future work is connecting those data to interview and other survey findings.

Data explorations for this part of the paper include:

1. Evaluation of the basic statistics for the IDI results (PO, DO, gap) for the whole student cohort
2. Evaluation of basic statistics for the IDI results broken out by institution
3. Evaluation of intercultural competence changes (pre/post) by institutional cohort

4. Evaluation of intercultural competence dependence on level of engagement
5. Evaluation of changes in engagement levels and intercultural competency for engineering students over their studies

3. Findings

This paper's work is divided into two major sections, the first (Section 3.1) focuses on better understanding the intercultural proficiencies of a large pool of engineering students at one university, the mid-sized public technical university. The second section explores the patterns among engineering students in a longitudinal study at five different institutions.

3.1 Technical University Results

Figure 2 shows the results of 149 engineering students completing the Intercultural Development Inventory at MPuT. The chart shows the frequency results for this population in two scales, the Development Orientation (DO) and the Perceived Orientation (PO). The intercultural development spectrum is positioned above the chart for easy reference. A few important findings are evident. First, the intercultural development of these engineering students reveal a majority Polarization mindset, with many in Minimization. Few students are beyond this range; few in Acceptance, fewer in Denial, and none in Adaptation. Second, students consistently evaluate themselves much higher developmentally than they actually are (i.e. PO is higher for all participants). This is a routine outcome, and not peculiar to engineering students, however the gap between the average PO (120.3) and DO (90.7) of 29.6 is worth noting, and yields two stages above the actual average (the average student thinking they are in Acceptance compared to actually being in Polarization). It is worth remembering that this engineering student body self-selected into a program focused on sustainable community development and engagement; while no formal interviews were conducted with these participants, anecdotally, many students in these programs describe both concern and affection towards the cultures of their community partners. As such, the form of Polarization within this cohort may be Reversal rather than Defense. To better understand some of these findings, the influence of program type was next explored.

The 149 students in the pool were pursuing one of five community engagement programs, each with a focus on sustainable development but each with a different level of service commitment. The first program was an optional senior capstone project taking place with a community in Central or South America, including two weeks of field work abroad. The second program was a graduate research program with a local service component developing sustainable development teaching materials with K-12 teachers based on the graduate student's research. The third program involved short-term (three months) of field research in East Africa embedded within a twelve-month long research program on small-scale infrastructure research. The fourth program was the Engineers Without Borders chapter at MPuT. The last student program was a graduate program comprised of one year of campus course work, followed by two years of field research in a community partnering with a non-governmental organization.

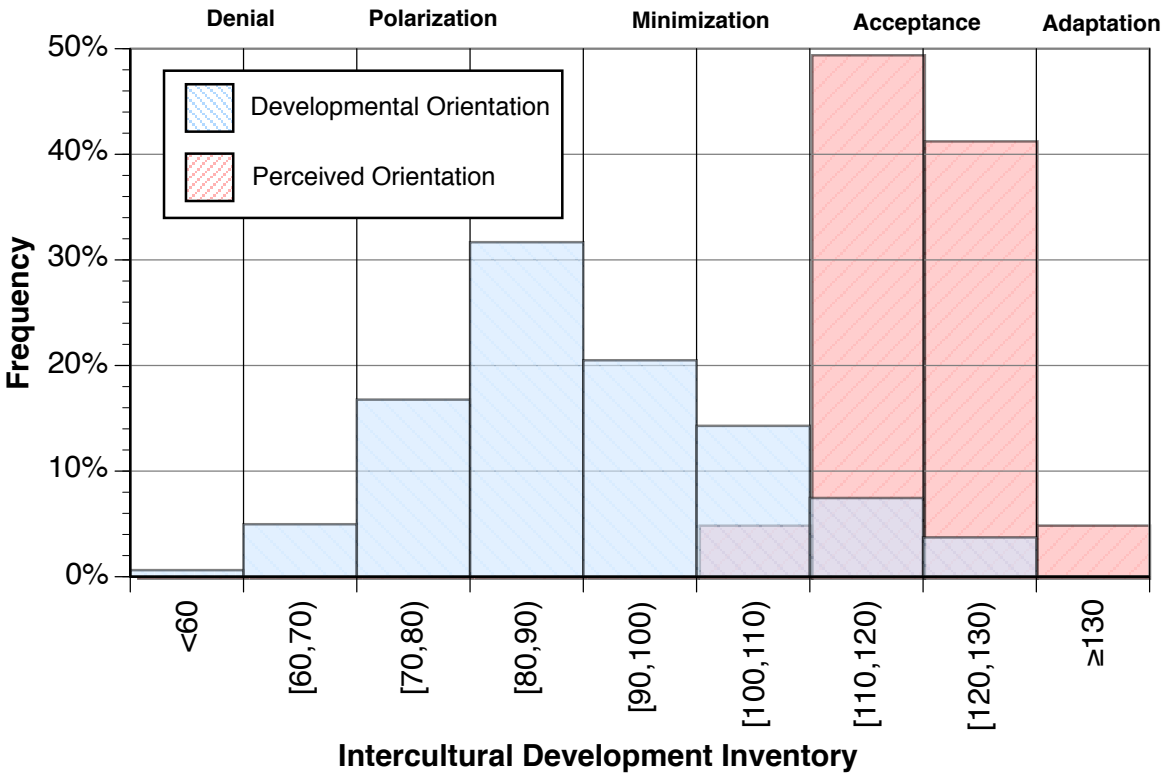

Figure 2. Distribution of IDI scores for engineering students beginning engagement with various sustainable development programs (n=149)

The students in these programs took the IDI early in their program involvement. As comparative data, many of the faculty champions of these programs also took the IDI. The IDI data (DO only), by program cohort, is shown in Table 1. None of the program means is significantly different (at 95% confidence), however there are interesting comparisons. On average students in the shorter engagement programs (international capstone, sustainability research, and Africa field research) tended to be in the transition stage between Polarization and Minimization. Students in the programs requiring longer commitments (EWB and the two-year abroad graduate program) reveal average student profiles in Minimization. The faculty demonstrate a similar position; this may be suggestive of challenges for engineering faculty to train their students in more advanced intercultural mindsets. The next section explores developmental trends associated with students' experiences with their faculty, peers, institutions and communities during their studies.

3.2 Five Institution Results

While it is helpful to the academic community to share findings from a particular university, the transferability of results to other institutions is rightly questionable. This part of the paper offers initial insights gained from a large multi-year research project to explore the influences of community engagement on engineering students and education. The project focused on the longitudinal surveys of 360 students at five institutional cohorts from 2011 to 2013; of these students one-third were randomly selected for additional involvement in the study, including

Table 1. Intercultural competence of students engaged in one of five sustainable development programs at a mid-sized technical university, as determined by the Developmental Orientation in the Intercultural Development Inventory (IDI). Data for faculty leaders of these programs is also included.

Program	Pre-Program IDI $\bar{x} \pm \sigma$ (cohort size)
International capstone project	87.3 ± 11.3 (n=53)
Sustainability graduate program	87.3 ± 18.9 (n=13)
Short-term international graduate research	89.7 ± 14.1 (n=10)
Engineers Without Borders	91.1 ± 17.5 (n=28)
Sustainable development program faculty	94.3 ± 14.1 (n=12)
Long-term international graduate research	94.7 ± 14.6 (n=45)

annual IDI evaluations and in-depth interviews. The IDI data and preliminary analyses are shared in this section in an effort to better understand connections between intercultural competency and service involvement, patterns of these two across institutions, and trends over time. Unlike the MPuT student cohort, this study's engineering student pool were random samples of the engineering student body at each institution (who were willing to volunteer to the solicitation).

Figure 3 shows the distribution of all initial IDI scores for the 120 students in this investigation. Similar to the MPuT study, the intercultural development of these engineering students reveal a majority Polarization mindset, with fewer in Minimization. Very few students are beyond this range; very few in Acceptance, few in Denial, and none in Adaptation. This profile is shifted more to the left than the MPuT distribution above. Also, students consistently evaluate themselves much higher developmentally (PO) than they actually are (DO) with a gap between the average PO (116.5) and DO (81.6) of 34.9. The gap is about 17% larger than that found in the MPuT students above. To make more sense of these differences, intercultural competence was explored at the institutional level.

3.2.1 Intercultural mindset by institution

IDI data was categorized by the five student institutions: mid-sized public technical university (MPuT, the same institution as in the study above, however with a completely independent student cohort than the study above), a large public undergraduate focused university (LPuU), a large public research university (LPuR), a small private research university (SPrR), and a cohort of students from Engineers Without Borders chapters at 12 other universities (EWB). Figure 4 shows the distribution and basic statistics of IDI scores across all three years at the five institutions. Each institution's box plot comprises all the IDI evaluations taken by the student

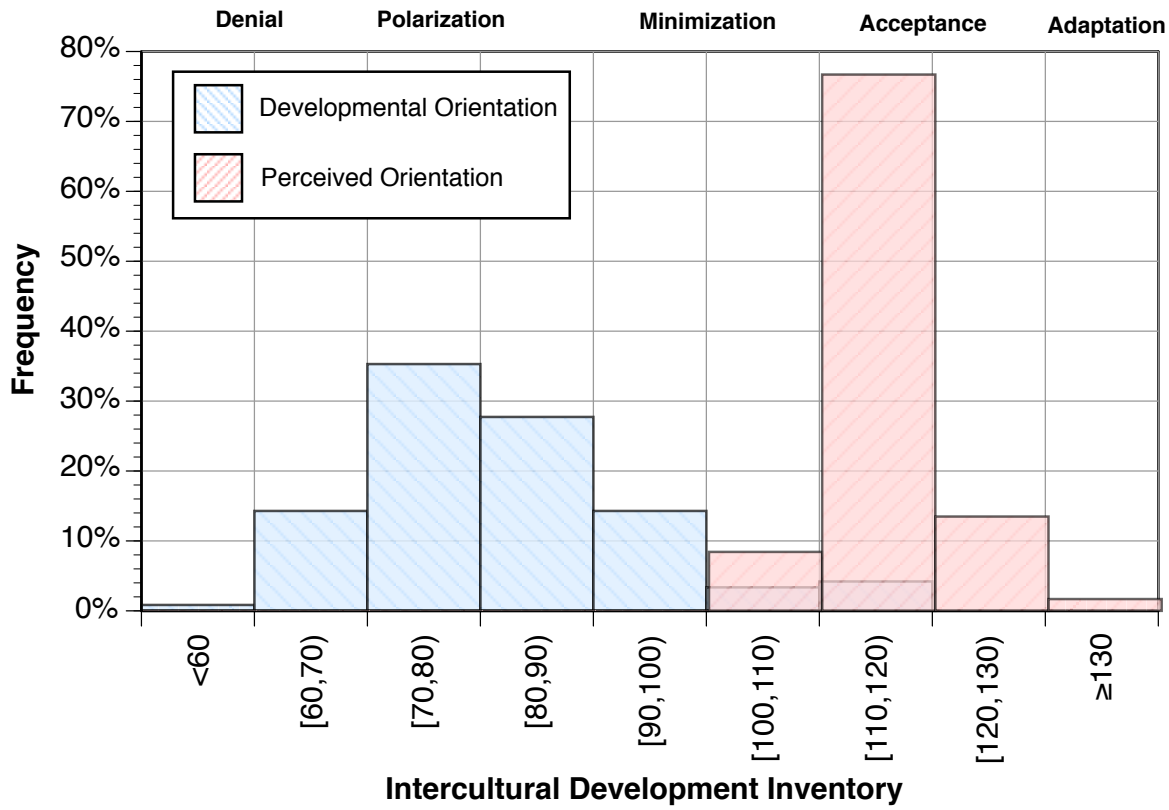

Figure 3. Distribution of "pre" IDI scores for engineering students at all five institutions (n=120) at the beginning of the three year study.

cohort from that institution over the three years. The overall number of evaluations (225 instead of 3 x 120 =360) is an indicator of the participation rate over the study, 62.5%. The IDI takes about 30 minutes to complete, so while participation was 100% in the first round, subsequent rounds resulted in diminished involvement due to the time investment for students and alumni.

No statistically significant differences were found in the average IDI scores across institutions. The more undergraduate oriented schools (MPuT and LPuU) showed lower IDI averages, both at the transition point between Polarization and Minimization. The research oriented schools (LPuR and SPrR) possessed higher averages (about 10 points higher). The EWB cohort also demonstrated similar levels to the research schools.

To move beyond the broad landscape analysis derived from grouping all scores into institutional cohorts, initial intercultural mindsets and their trends were next analyzed by institution. This analysis includes only participants with two or three IDI assessments over the three year period in order to establish a trend for each individual. Table 2 shows these results. While there are no statistically significant differences in average initial IDI scores among the institutions, the pattern observed earlier is reproduced — cohorts at undergraduate oriented schools were notably lower and positioned at the transition point between Polarization and Minimization. In this analysis,

EWB students demonstrated an intercultural mindset further along the monocultural phase, but still fully positioned in Minimization.

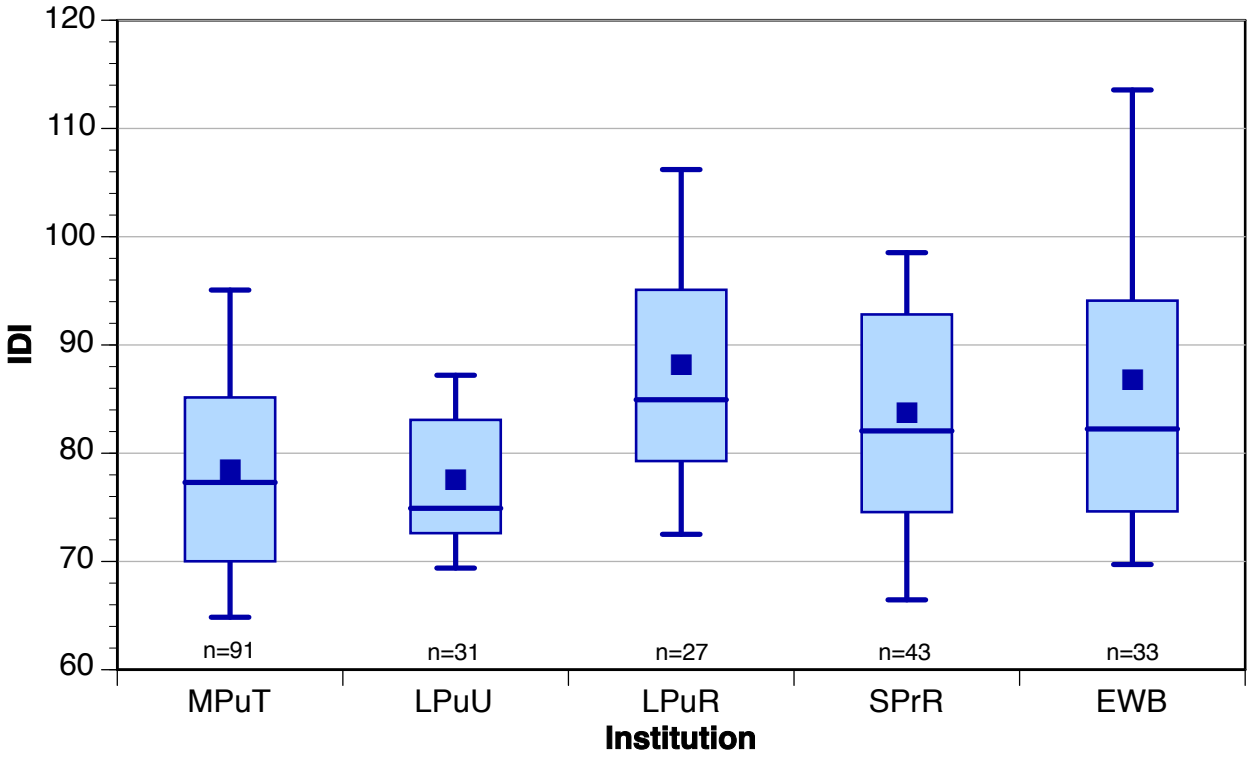

Figure 4. Boxplots showing distribution of all IDI scores (Developmental Orientation) for all students at each institution in the five institutions over the three year longitudinal study.

Table 2. Comparison of average initial intercultural competency (as measured by the IDI Development Orientation) and the average change rate by institutional cohort

Institution	Average starting IDI	Average change in IDI
LPuU (n=12)	75.3	2.17%/yr
MPuT (n=34)	76.5	2.53%/yr
LPuR (n=11)	82.4	3.88%/yr
SPrR (n=17)	86.7	-3.24%/yr**
EWB (n=12)	87.8	-0.18%/yr

** $p < 0.05$

Importantly, the longitudinal nature of the dataset permitted an examination of trends in these mindsets, and begins to reveal differences among institutions. While three of the university cohorts demonstrated developmental gains with time, on average 2-4%/yr, the SPrR cohort produced a statistically significant average downward trend, decreasing more than 3%/yr in IDI scores. Also of interest was the almost unchanged intercultural mindsets of the EWB student cohort.

3.2.2 Intercultural mindset by service level

To begin to further explain differences, patterns, and trends, self-reported community engagement (service level) from biannual surveys of the study's student participants was coupled to their IDI data. Differences in service level among the institutional cohorts might then be used to explain the above discoveries.

Figure 5 depicts the influence of service on intercultural competency. The figure uses average self-reported service and average IDI (Development Orientation) for each student participant, combining all five institutions in one plot. In summary, the level of community engagement seems to have no connection to predicting the intercultural mindset of those engaged; there is no correlation between the two ($r^2 = 0.0007$). As such, no further work exploring interconnections between the two were pursued; instead pattern analysis within the data was next explored.

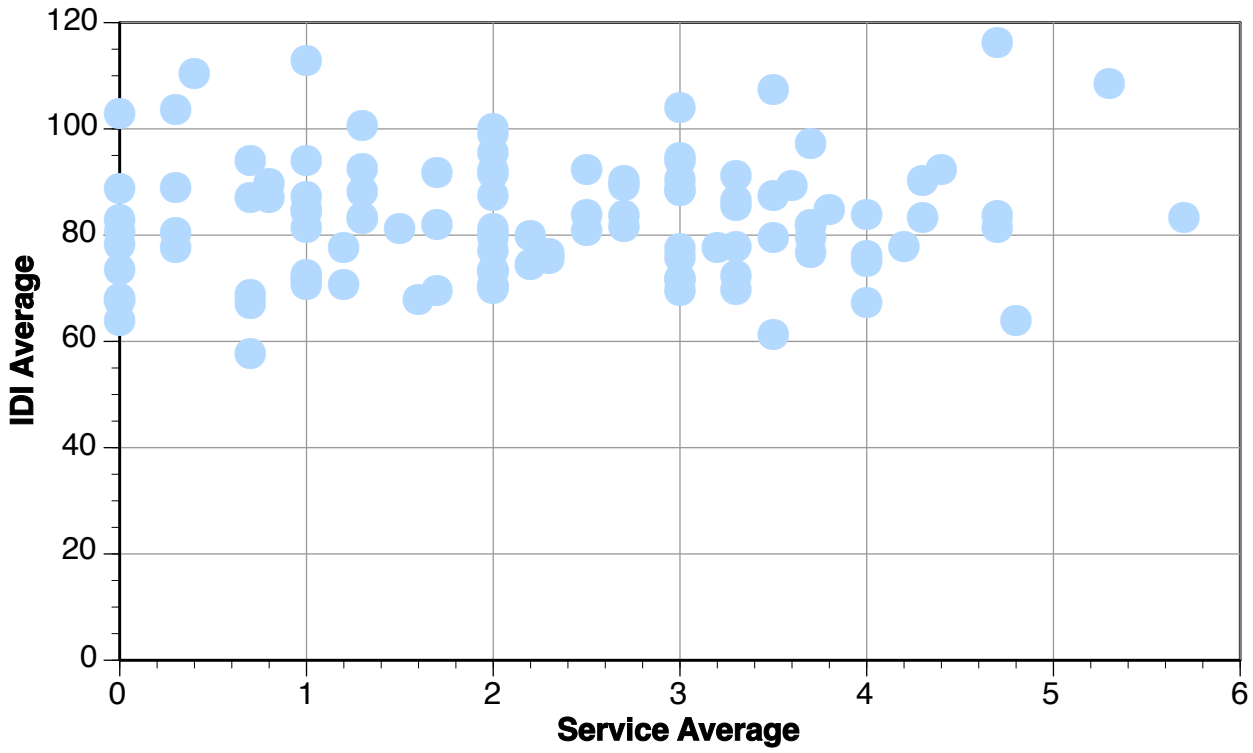

Figure 5. Scatterplot showing average self-reported service involvement and IDI scores (Developmental Orientation) for all students at all institutions over the three year longitudinal study.

3.2.3 Intercultural competency and service patterns

The next evaluation explored engineering students' longitudinal trends in intercultural mindset and in engagement. Students in all five institutions were divided by their self-reported levels of engagement (none, some, high) at their initial and final points of involvement in the study subsequently resulting in nine Pre-Post service categories (None-None, None-Some, etc.). Table 3 provides several key findings.

At the beginning of their involvement with the study, 29.4%, 52.9%, or 17.6% of the five institution engineering participants described their level of engagement in service opportunities as None, Some, or High, respectively. By the conclusion of the study, nearly three years later, these same students (only 85 of 120 with complete pre/post data) categorized themselves as None, Some, or High at 18.8%, 48.2%, or 32.9%, respectively; in general engineering students become more engaged with service opportunities over their time as students. Also, service disposition appears to be more entrenched at higher levels of engagement; 40% of students starting at None stay at that level (post vs. pre), whereas 56% of those starting at Some remain unchanged, and 73% of High remaining unchanged. Lastly, it is worth noting that no student who started with a high level of engagement reported dropping to no engagement by the end of the study.

Table 3 also summarizes trends in IDI by category of service change. While overall patterns are muddled (as might be expected from the correlation work above), there are two important sub-patterns: students who start at a high level of engagement show gains (average) in IDI score; and regardless of starting level of engagement, all students who finished at a high level of engagement showed gains (average) in IDI.

Table 3. Trends (%/yr) in intercultural competency (as measured by the Intercultural Development Inventory) as dependent on the initial (pre) and final (post) self-reported service involvement of students in all five institutions (n=85) in the three year longitudinal study. Number of students in each category in parentheses ( ).

Post \ Pre	**None n=25**	**Some n=45**	**High n=15**
None n=16	3.36%/yr (10)	0.92%/yr (6)	n/a (0)
Some n=41	-2.18% (12)	-0.49% (25)	7.13% (4)
High n=28	0.22% (3)	2.6% (14)	2.49% (11)

As average patterns can obscure the realities for individuals, a few additional relationships were explored at this level. Figure 6 shows the individual changes (in service and intercultural competency) for all students in the five institutions study. Overall, 49 of 85 engineering students (57.6%) reported an increase in service involvement over their time in the study (and school), whereas 23.5% decreased involvement, and 18.8% did not change. In contrast, 49.4% increased and 50.6% decreased in intercultural competence, respectively. For additional insight into a population of engineering students these findings can also be derived within the distributions of the individual changes in service and intercultural competency, as presented in Figure 7. Both figures reveal details hidden in previous analyses based upon cohort averages; specifically what "extremes" are possible within the student body. A small number of students move from None to High in engagement, for example (note: percent change in engagement cannot be presented as participants could report an engagement score of 0, for no service involvement; instead units of change on the 0 to 6 point Likert scale from the survey are presented). In intercultural competency, more than 13% of students increased their IDI at more than 10%/yr, and conversely 7% decreased at more than 10%/yr. The experiences of such students are especially ripe for exploration via interview analysis.

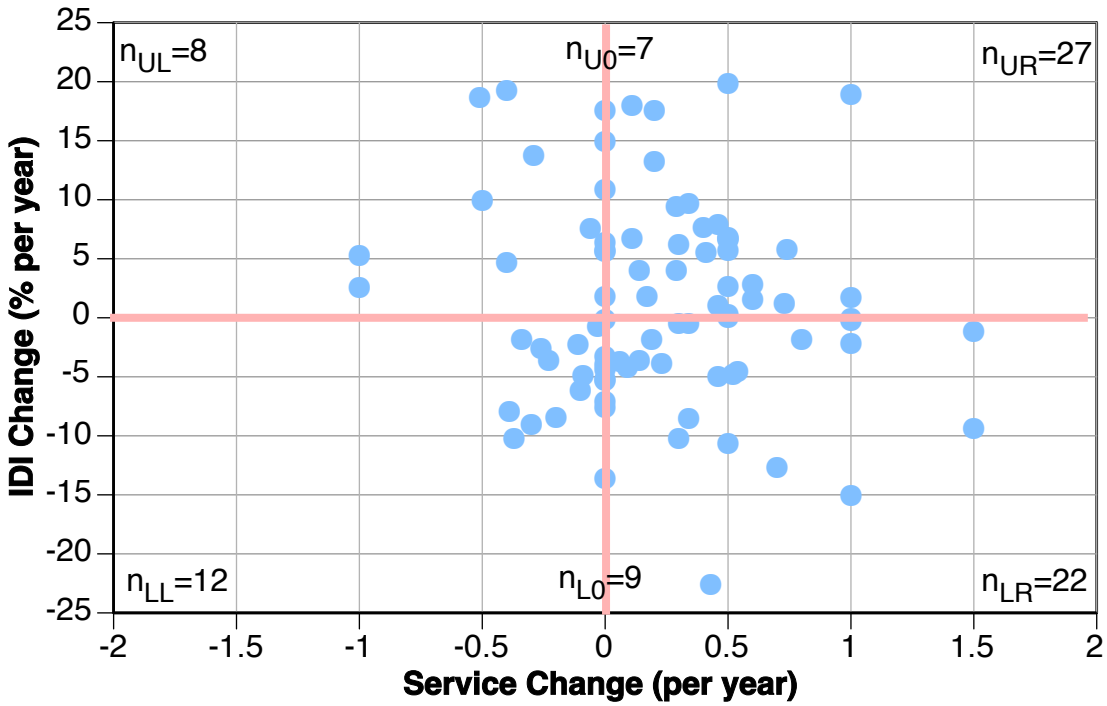

Figure 6. Scatterplot showing changes in IDI scores (Developmental Orientation) and self-reported service involvement for all students at all institutions over the three year longitudinal study. Each dot represents a different student. n=number of students in each sector of the landscape (lower, upper, left, right, no change).

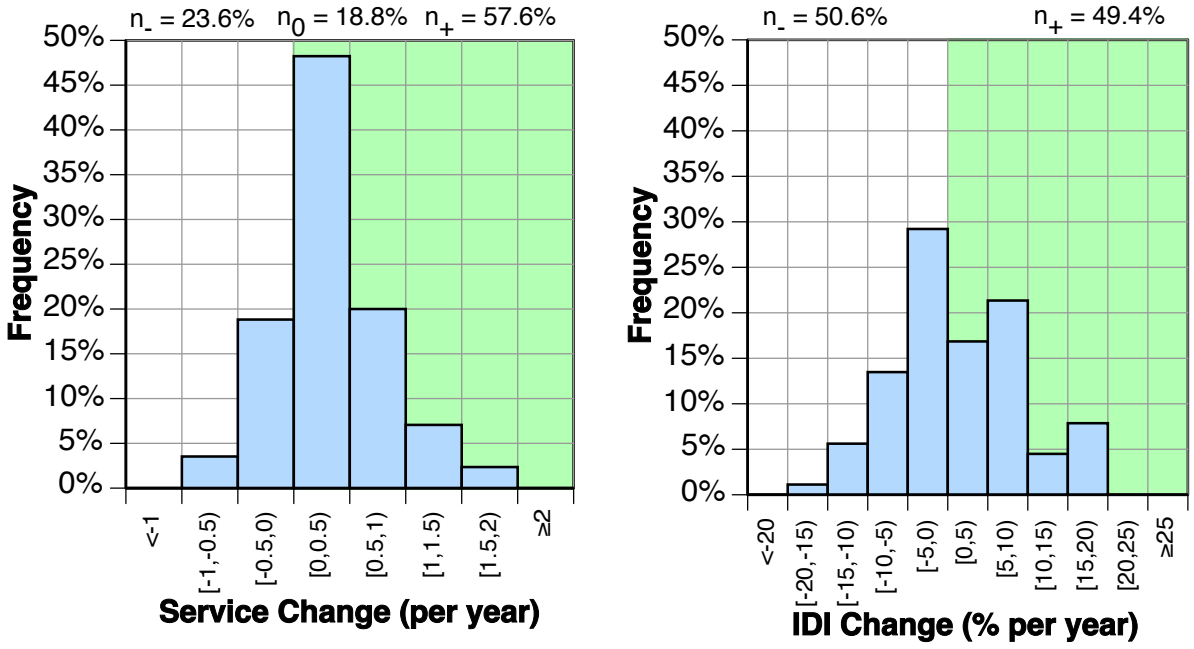

Figure 7. Histograms showing the distributions of changes in self-reported service involvement and IDI scores (Developmental Orientation) for all students at all institutions over the three year longitudinal study. Percentage of population shifting higher (+), lower (-), or no change (0).

3.4 Conclusions and Recommendations

This paper presented findings from two datasets, the first focused on students from one university, and the second on students from five institutions. The first dataset offered an overview of the intercultural mindsets of students upon entrance to optional community engagement programs with a sustainable development focus, whereas the second dataset was derived from a unique three-year longitudinal study involving intercultural attitudes, and service engagement among many other features. Together, these two datasets provide a few important findings connected to the two hypotheses underlying this work:

> Major findings for ***H1:*** *Service-oriented international experiences attract engineering students with an intercultural mindset*
>
> - Investigation of student participants in the various programs at the mid-sized public technical university suggest that the students with a more developed intercultural mindset could have a greater preference for programs with higher personal commitments for community engagement. Not only did the average IDI score increase among programs with more intense service requirements, but comparing the average IDI of these programs to a broader mix of students from the same school in the five institutions dataset reveal a substantial difference (90.7 versus 76.5).

- A secondary finding is the potential challenge to engineering faculty in leading students down a developmental path in intercultural competency based on the similar average levels in IDI scores between faculty and students. As the construction and navigation of learning experiences is predicated upon instructor mindset, it seems a reasonable conclusion that faculty would find it difficult to effectively mentor students to a cultural mindset more complex than their own. On a more positive note, faculty engagement in such service programs may serve as professional inspiration for students, although this awaits future study.

Major findings for ***H2:*** *Participation in service-oriented experiences will lead to elevated intercultural proficiency for engineering students*

- The findings in the five institution study are clear — community engagement experiences do not translate to more refined intercultural development. While some students do make such gains, an equal number do not, and generally movements are small in either direction. A much smaller fraction of students undergo seemingly large shifts in their intercultural perspectives; understanding motivating causes will require considerable analysis of the interviews and additional surveys captured in the larger research project, and even then the influences may be difficult to ascertain.

- A related discovery of the findings from the five institutions is that engineering community engagement experiences are not designed or facilitated to encourage intercultural development of the participants. Understandably there is engineering work to be done, and this work (often design and build) is motivated by technical imperatives. Unfortunately, there is growing anecdotal evidence in the global development community of the costs that this narrowly-defined "engineering efficiency" can have on the ultimate lack of appropriateness and effectiveness of engineered works.

When it comes to intercultural competency, going is not knowing. Engagement with the world's communities does not necessarily translate to understanding more about them (at least with a higher level of cultural sophistication); it's evident that something is missing developmentally in most engineering student service opportunities. Observationally, these experiences seem to be powerful disruptions in the short-term, if not longer, attitudes of the participants; however it is clear from this study that it must be in ways other than intercultural competency. A summative conclusion from this work is directed at the engineering faculty, rather than the student participants upon which this paper is built. Despite many engineering service experiences being led by well-intentioned faculty, the unfamiliarity (and, for many, lack of proficiency) with intercultural thinking may undermine genuine efforts for inclusive and effective community-based engineering efforts. Not all is hopeless, however. Like good practice in the delivery of engineering projects in service contexts, the solution for better *educational outcomes* is also likely to be found in smart partnerships — in this case with campus colleagues adept in the complicated fields of community engagement, and, especially, intercultural development. A service learning class at Minnesota State University[14] found significant improvements in student

IDI scores by introducing three interventions: in-class discussions with international students, a service project coupled to a local cultural event (attending a Native American PowWow), and one-on-one feedback for each student on their cultural orientation. It may be these types of structured influences should be required, yet they are commonly missing from the typical project-based engineering service experiences. Future work should focus on controlled experiments to existing service programs to determine program elements that benefit our communities by creating a generation of engaged and more culturally aware engineers.

4. Support

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