

Evaluating Humanitarian Engineering Education Initiatives: A Scoping Review of Literature

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CONTEXT Humanitarian Engineering (HumEng) is a rapidly emerging discipline in Australian and worldwide engineering education curriculum. While many engineering courses have been incorporating international service-learning pedagogy, it is only in the recent decade that engineering schools have started offering degrees in HumEng and this trend seems to be increasing. Among the many challenges that engineering schools face, major efforts will be focused on evaluating the outcomes of these new degrees and HumEng learning interventions across the engineering curriculum.

PURPOSE The goal of this study is to develop a preliminary understanding of the evaluation strategies and outcomes that have been used to evaluate existing HumEng curricular or co-curricular initiatives.

APPROACH As a starting point, we focused our search on studies published in the *International Journal of Service-Learning in Engineering* (IJSLE), which has been the main outlet for research focused on international service-learning in the past decades. From IJSLE, we identified over 40 peer-reviewed articles that reported evaluation of HumEng and similar programs. We analysed the collected articles using a qualitative content analysis approach, with a focus on what outcomes the studies assessed and what instruments were used.

RESULTS The results of the content analysis showed that two main aspects have been evaluated in these studies: students' satisfaction with the courses/programs and development of competencies. In terms of students' satisfaction, the studies reported that students tend to see more value in HumEng and similar initiatives as compared to traditional courses. In terms of competencies, the studies have assessed numerous technical and professional skills, usually finding that HumEng and similar initiatives are effective in supporting the development of such competencies. However, the analysis revealed several limitations associated with the evaluation procedures used in the studies.

CONCLUSIONS This preliminary review showed that HumEng offer many benefits to students especially in terms of their professional development and the enhancement of competencies highly desired by industry. Our analysis also identified many potential gaps in the literature, including scarcity of rigorously validated instruments to evaluate learning outcomes, lack of focus on impact of initiatives on students' identity and career choices, and community partner's perspectives. Consequently, we conclude the study suggesting ideas for future research projects and recommendations for evaluating HumEng programs.

KEYWORDS Humanitarian Engineering, Service-Learning, Evaluation, Literature Review.

Introduction

Humanitarian Engineering (HumEng), global and local service learning, and similar courses, programs, and educational initiatives have been becoming increasingly popular in engineering education courses worldwide. These trends started with the creation of engineers without borders (EWB) chapters, the first being in France (Paye, 2010), and expanded rapidly. In 2003, EWB-International was created as a network that connects 41 national member organizations (Lucena and Schneider, 2008) and many others have been established since. In the past decades, HumEng has also moved from extra-curricular activity to become the subject of a higher education engineering degree. The first institution providing degrees in HumEng were in USA, with the first one probably the minor in Humanitarian Engineering at Colorado School of Mines established in 2003.

In Australasia, the main focus on humanitarian engineering has been driven by the educational efforts of EWB-Australia, which have offered multiple educational initiatives for many years. Building on these initiatives, Australasian engineering schools have started offering courses focused on humanitarian engineering and the first degree in Humanitarian Engineering was open in 2017 at the University of Sydney (University of Sydney, 2016). UoSydney however is only the first institution among many that are starting to offer degrees in HumEng.

Among the many challenges that engineering schools will face, major efforts will be focused on evaluating the outcomes of these new degrees and HumEng learning interventions across the engineering curriculum. To start brainstorming ways of addressing this challenge, we reviewed literature that has been published in the International Journal of Service Learning in Engineering (IJSLE), the main outlet for local and global service learning research. Specifically, we asked the following research questions:

1. What was the focus (e.g., students' satisfaction, skill development, etc.) of the evaluation?
2. What methods were used to perform the evaluation?
3. What was the quality of the quality of the procedures used for the evaluation?

Methods

To obtain preliminary answers to our research questions, we undertook a "scoping review" of literature (Grant & Booth, 2009). As explained by Grant and Booth (2009), a scoping review provides a preliminary assessment of the available literature on a chosen topic and shares "characteristics of the systematic review in attempting to be systematic, transparent and replicable" (p. 101). Therefore, a scoping review was especially appropriate in the case of this study as our goal was to develop a preliminary picture of previous efforts to evaluate HumEng and similar learning experiences.

Data collection

For this paper, we chose to focus on the International Journal of Service Learning in Engineering (IJSLE) because it has been the main outlet for research publication on HumEngEd and related topics. This choice allowed us to focus on a smaller set of data and conduct a preliminary assessment, which is in line with the goal of a scoping review.

The data collection process was adapted from the PRISMA process (Moher et al., 2009), which is usually used for systematic literature reviews (Borrego et al., 2014). The PRISMA process is comprised of four steps: 1) identification of literature through systematic searches of databases, 2) screening of abstracts to discard papers that do not meet selection criteria, 3) appraisal of full-text to discard papers that do not meet selection criteria and/or do not meet quality standards, and 4) analysis and synthesis of collected literature.

In our scoping review, we skipped the first step (identification through database searches) and we focused only on IJSLE as mentioned above. Therefore, we went directly to the abstract screening phase. The first author reviewed all the abstracts of the papers in IJSLE archives up to issue 2 of volume 11, which was the last published issue when the search was conducted, and therefore no keyword search was employed. The main selection criterion was that the paper had to present a research study focused on evaluating the learning experience of the students enrolled in a service-learning course. The abstract screening resulted in 46 papers.

Next, the two authors appraised the full-text of the paper to make sure that the papers presented some sort of evaluation study. In contrast with systematic literature reviews that assess the quality of the a study at the full-text appraisal stage to decide whether to keep or discard a journal article, in our case we did not appraised the quality of the papers at this stage because evaluating the quality of the collected papers was part of our research goals, so we wanted to keep even lower quality studies. To appraise the full-text, the two authors selected 10 papers from the 46 and appraised them independently. Then, they met to compare results. Because the results were very similar, the two authors appraised the remaining 36 papers independently. To evaluate, the extent to which the two authors agreed on the appraisal of the 36 papers, Inter-Rate Reliability was calculated using Cohen's kappa. The resulting kappa was 0.94, suggesting almost perfect agreement. In fact, the two authors disagreed on one paper of the 36. The two authors decided to keep the paper. At the end of the full-text appraisal, we were left with 21 papers to analyze.

Data analysis

To analyze the 21 papers we used a content analysis (Hsieh & Shannon, 2005) approach. First, the two authors analyzed half of the papers independently, with a focus on information related to the three research questions: 1) focus of the evaluation, 2) procedures of the evaluation, and 3) quality of the evaluation process. Once the two authors completed the analysis, they met to compare and discuss their coding. They came to agreement on the final codebook and coded the remaining papers independently. Finally, they met again to compare the second round of coding and finalizing the findings.

Results

The goal of our scoping review was to gather preliminary information on the focus, methods, and quality of evaluation of the evaluation presented in the papers. Therefore, we organized the results section around these three topics.

Focus

The specific focus of the evaluation studies presented in the 21 papers ranges significantly, but we grouped them in two broader categories: learning outcomes and satisfaction. As reported in table 1, the majority of the papers ($n = 15$) focused on learning outcomes, while seven papers evaluated stakeholders' satisfaction. Two studies (Davis et al., 2014; Leigh & Clevenger, 2013) evaluated both learning outcomes and satisfaction. In general, all papers reported that students gained proficiency in the outcomes measured as a result of participating in the respective HumEng or related initiative, which included short intensive courses, one semester courses, and multi-semester courses.

Among the learning outcomes that were evaluated the most common were social responsibility, teamwork, and communication. Other common competencies included global/cross-cultural skills, design, problem solving, and life-long learning. The fact that these specific skills were most commonly studied is not surprising as HumEng initiative have an intrinsic focus on professional skills, community engagement, and design across countries and cultures.

Table 1. Number for papers for each focus of evaluation	
Focus	N of sources
<i>Learning Outcomes</i>	15
Social responsibility	7
Teamwork	7
Communication	7
Global/Cross-cultural	5
Applying STEM knowledge	4
Design	4
Problem solving	4
Life-long learning	4
Equity and diversity	3
Leadership	2
Project management	2
Creativity	2
Others cited only once (e.g., reflection, self-efficacy, cognitive processes, and others)	10
<i>Satisfaction</i>	7
Students	6
Community partners	3
Faculty	1

However, although the papers used similar names for each competency evaluated, there was not much agreement among the specific definitions of each competency. For instance, the learning outcome focused on social responsibility comprised a range of different, but closely related perspective. Carberry et al (2013) frame it as an individual ability of identify potential ethical issues and dilemmas of a project. Others instead focused on community engagement. Bratton (2014) evaluated students' ability to understand technology impact and Songer & Breitkreuz (2014) focused on global citizenry. Many of the professional competencies overlapped among each other and it was to some extent difficult to put them in one single box. For example, in assessing project management, Davis et al. (2014) included also "working well with a team on an engineering project", which other papers would have categorized as teamwork. Therefore, while authors of the 21 papers used similar language for the learning outcomes, there was often some discrepancy in terms of the actual meanings. Nonetheless, the coding in table 1 reflects the authors of the collected papers wording rather than our perceptions (e.g., if they used the word "teamwork" we coded it as teamwork even if the definition overlapped with other competencies).

Among the papers that evaluated stakeholders' satisfaction, students' perspective was the one that was mostly appraised. Similarly to the case of the learning outcomes, each paper looked at different, but closely related aspects. To cite a few examples, Bargar et al (2016) asked students to reflect on their experience as compared to traditional coursework, Bichel & Sundstrom (2011) asked to rate the "quality of the course content", and Liguori et al (2014) elicited perspective on the academic structure and the teamwork experience. The community partners were typically surveyed about their satisfaction of working with the students. Only Ermilio et al (2014) included faculty members. However, while students, community partners, and faculty members are key stakeholders, HumEngEd involves even a wider range of stakeholders (e.g., governments, other local organizations, the direct beneficiaries, professional staff of universities, accreditation bodies, professional societies, etc.), which could be included in future research.

Methods

In terms of methods of evaluation, we grouped the methods used in the traditional three categories: quantitative, qualitative, and mixed methods. Quantitative methods were the most commonly used ($n = 12$), followed by qualitative ($n = 5$), and finally mixed-methods ($n = 4$).

Among the quantitative studies, surveys using Likert scales were the most common. For instance, Bielefeldt and Canney (2014) used the Engineering Professional Social Responsibility Assessment survey, which is comprised of 50 items on a 7-point Likert scale. Similarly, Bratton (2014) used the Engineering Self-Efficacy Scale (ESES) which is comprised of 13 items on a 7 point scale. Only one study did not use Likert scale. Budney and Gradoville (2011) asked students to rank a set of 20 competencies from the most important to the least important.

Although many studies focused on evaluating similar outcomes, none of the quantitative study used the same instruments. The only papers that used similar surveys were Perrakos et al (2014) and Carberry et al (2013). In fact, Carberry et al. (2013) used an adaptation of National Engineering Students' Learning Outcomes Survey (NESLOS), whereas Perrakos et al (2014) used the original. The lack of consistency among methods used for measuring the same constructs in these quantitative studies is somewhat surprising as one of the strengths of quantities methods is they enable comparison through standardization.

Among the qualitative studies, reflections were the methods mostly used. Duff et al (2014) and Leigh and Clevenger (2013) collected reflections from students only at the end of the learning experience, whereas Jeffers et al (2015) asked students to reflect before, during, and after their experience. Liguori et al. (2014) was the only study that used interviews as the main method to collect information for their evaluation. The most unique approach was probably used by Lemons et al. (2011), who utilized verbal protocol analysis.

Finally, only four papers used a mixed-method approach. Dukahn and Schumack (2010) combined reflections and multiple-choice questions. Smith et al (2016) grounded their study in Threshold Concept Theory and used both surveys and interviews. Ermilio et al (2014) ran a SWOT analysis with multiple stakeholders and interpreted findings from Likert scale surveys. Perrarkos et al. (2013) integrated surveys with open-ended questions.

In sum, a range of methods has been used, with a clear preference for surveys. Only two non-mainstream approaches were utilized (Verbal Protocol Analysis and SWOT). The most surprising finding was probably the lack of consistency of the methods used among the papers, which prevents any meaningful comparison to be made.

Quality

The last part of our analysis of the papers focused on assessing the quality of the research strategies presented in the studies that we collected. We ranked the studies as high when they presented a complete description of the procedures used and a sound justification of their design choices, as medium when some aspects were missing, and as low when no information on the research design was provided. Overall, we rated only 5 articles as high quality and three as medium. The large majority ($n = 13$) did not present enough information on their study design and therefore we had to rate them as low quality.

Among the five articles that we rated as of high quality, two (Bielefeldt & Canney, 2014; Carberry et al., 2013) were quantitative methods, two were qualitative (Jeffers et al., 2015; Lemons et al., 2011), and one was mixed-method (Pierrarkos et al., 2013). The three studies that used a quantitative approach (Bielefeldt & Canney, 2014; Carberry et al., 2013; Perrarkos et al., 2013) presented very clear description of the theoretical framework underpinning the instruments they used and the validation process that was followed to make sure that the surveys were actually validated and reliable. Similarly, also the qualitative studies presented a theoretical framework and provided details on the procedures for data collection and analysis as well as ways to ensure the trustworthiness of their studies.

Discussion and future research

In this study, we provided a preliminary overview of the focus, methods, and quality of evaluation studies that focused on HumEngEd and similar initiatives. Although our study is limited to ISJLE, four interesting insights emerged from our analysis. First, we found that there is a lack of consistency in the learning outcomes that were evaluated across the papers, thereby making it difficult to perform meaningful comparison across initiatives. Second, the evaluations have been mostly focused on students, thereby missing a broader range of perspectives from different stakeholders. Third, evaluations have mostly used a limited number of traditional methods, which may be positive for standardization, but it also may limit the types of information that can be gathered, especially when collecting information from projects that have a practical application focus. Fourth, while all the studies showed positive results, the lack of details of the research procedures for evaluation makes it difficult to draw solid conclusions on the benefits of HumEngEd initiatives for students and other stakeholders.

In light of these insights, we recommend that three related areas of research should be undertaken. The first line of research should focus on creating a consistent framework of competencies or learning outcomes that could be applied across the current and future HumEngEd programs across Australasia. A possible approach to this problem could be to undertake a Delphi study and involve multiple stakeholders, including university, industry, local communities, and non-for-profit organizations. For instance, Deardorff (2006) used the Delphi technique to construct a comprehensive framework for defining and assessing intercultural competence.

Second, more research is needed to understand perspectives, motivations, and impact of multiple stakeholders, especially community members and partner organizations and the effect of geographical locations on stakeholders' perspectives. Some efforts to investigate this aspect in local service-learning programs has already been undertaken. For instance, Thompson and Jesiek (2017) developed the Transactional, Cooperative, and Communal framework to describe the nature of partnerships in engineering engagement programs. Such a framework could be used both to evaluate existing partnerships, but also to guide the creation of new partnerships between engineering programs and community partners.

The third line of research is focused on methods of evaluation. This line is directly connected and dependent on the two aforementioned research areas. As a new framework of competencies or learning outcomes is created, the attention could shift on how to actually assess students' learning as an outcome of these initiatives. It would also be interesting to go beyond traditional surveys and interview approaches, and use existing or develop new methods. For instance, a large body of evaluation research has used scenario-based instruments to evaluate a variety of engineering competencies, including, for instance, design thinking (Atman et al., 2014; McKenna, 2007), sociotechnical thinking (Mazzurco et al., 2014), and moral reasoning (Borenstein et al., 2010). Furthermore, evaluation procedures such as program logic and similar should be considered.

Finally, a larger, more rigorous systematic literature review should be undertaken in order to confirm or reject the four aforementioned insights and inform further research.

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