

Many Hands on the Elephant: How a Transdisciplinary Team Assesses an Integrative Course For the Evidence-Based Practice Category of ERM

Abstract:

This paper, for the Evidence-based Practice category of the ERM division of ASEE, describes our efforts to assess a transdisciplinary course that brings together the humanities and engineering — specifically history, ethics, theatre, writing and literature with fluid mechanics, material properties, statics, stress and engineering design. We briefly describe this two-course, first-year curriculum that combines role-playing with engineering design and the engineering concepts necessary to develop culturally appropriate, human-centered waste management systems. The course breaks new ground in transdisciplinary teaching by employing faculty from engineering, the humanities, the social sciences and business who have worked collaboratively to develop the syllabus and who commit to being present at most class meetings. Because of this deep integration, our challenge was to design and implement an assessment system that would do justice to the different disciplinary content, including integrated content, with their diverse approaches to assessment —and to capture, as well, student ability to transfer and integrate knowledge across domains. This paper describes our assessment methods and explores the difficult collaborative process we undertook to design these methods.

The blind men said to each other, “what is an elephant?” But, as none of them had ever seen an elephant, none of them could give an answer. Because the six blind men very much wanted to find out what an elephant looked like, the next day they set out for the village to find the elephant.
—Indian folk tale

Introduction and Statement of the Problem:

In 2004, The National Academy of Engineering published *The Engineer of 2020: Visions of Engineering in the New Century* [1]. That report drew on insights about the rapid pace of technological innovation, the globally interconnected world that will produce and receive new technologies, the increasingly diverse populations that will be affected by technology, the profound effects of social, cultural, political, and economic forces on the success of technological innovations, and the increasingly transparent and significant presence of technology in everyday life (p. 53). Because of these dramatic changes in the world’s population, technologies, and interconnections, the authors of *The Engineer of 2020* concluded that in addition to a solid foundation in the principles of science, mathematics, and “domains of discovery and design,” the new engineer must also possess strong analytical skills, practical ingenuity, creativity, communication skills, mastery of the principles of business, management, and leadership, high ethical standards and a strong sense of professionalism, a flexible and resilient disposition, and the ability to be lifelong learners (pp. 54-56). ABET requirements for student learning outcomes match these attributes, ranging from the technical (ability to apply knowledge of mathematics, science, and engineering and to design experiments and systems, for instance) to the more comprehensive liberal educational outcomes such as “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.”

Both accounts aspire to an engineering education that resembles liberal education, described by the AAC&U as “an approach to learning that empowers individuals and prepares them to deal with complexity, diversity, and change.” Liberal education outfits students with “broad knowledge of the wider world” as well as deeper disciplinary study. This combination of disciplinary and integrative learning “helps students develop a sense of social responsibility . . . and a demonstrated ability to apply knowledge and skills in real-world settings” [2].

In many cases, engineering students are expected to learn these wide-ranging abilities through general educational requirements that separate humanistic or social science learning from STEM content. Thus, however lofty the goals of both the NAE and ABET, the burden of making connections between courses and disciplinary learning often falls on the students, with few opportunities for integration before the senior capstone design course. We cannot say whether a curriculum that includes many engineering courses and some humanities courses is truly integrative. Do the educational components that provide students opportunities to study social contexts also consider technology as a subject within those contexts? If not, can we really expect engineering students to acquire what ABET describes as “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context”?

The evidence that prompts our work is a body of compelling assessments of educational experiences that integrate STEM and humanities, demonstrating positive student outcomes including increased motivation and engagement [3, 4], deeper learning and longer retention of content [5, 6], developing habits of self-directed and lifelong learning [7,8] transfer of knowledge from one domain to another [9, 10], satisfaction with college [9], increased imagination or creativity [11,12.], and so on. While NAE, ABET, and other professional organizations are interested in seeing learning outcomes that require study in both the humanities and engineering, some of the research cited below further indicates that these integrative learning outcomes are best developed through educational experiences that are themselves integrative. However, the existing research into the effectiveness of integrative study is limited by inconsistent assessment efforts and the extreme difficulty of doing controlled, randomized experiments on student educational experiences[13, 14].¹ Our evidence-based practice builds on this diverse if inconclusive evidence of effectiveness in two ways:

- By designing, piloting, and redesigning a course that integrates engineering and humanities;
- By piloting a wide variety of assessments, based on the literature [15, 16, 17, 14, 18, 13, 19, 20,], and assessing those approaches to understand which are most effective in recognizing student learning outcomes of integrative courses.

In this way, we are identifying those assessments that will help support future work in the research of integrative learning.

What are these best practices for mutual integration of engineering and humanities learning experiences? How have the most integrative pedagogical experiments been assessed? What work remains to be done in assessing student engagement and learning outcomes in such courses? How could our team, having experimented in designing and teaching a first-year integrative engineering-humanities course [22, 23, 24, 25], help to advance knowledge about best practices? These are the challenges that our team of engineering educators is attempting to address. We are not alone in experimenting with truly integrative course and project experiences for students. Indeed, although most institutions have not yet found a way of integrating STEM and humanities learning within a single course, a surprising number of these experiments have been tried [26, 16, 11, 12, 3, 4, 27], including in the first-year curriculum [28, 29, 30, 31, 32, 33]. In spite of the richly varied examples of integrative learning, assessments have been much more scarce. It is not a difficult matter to assess disciplinary content within an integrative course; in our case, we had disciplinary experts assess the discipline-specific student work within disciplinary and interdisciplinary assignments. It

¹ One intriguing exception [5] considers the inherently integrative “problem-based learning” in a medical program, controlling for selection bias and concluding, in contrast to quasi-experimental studies that do not account for selection bias, that medical knowledge is higher for students involved in problem-based education.

is much more difficult to assess how well students learn to think across disciplinary lines or to incorporate one kind of thinking in a different disciplinary context. When thinking about how to assess student learning in a course that integrates STEM and humanities content, we find ourselves feeling a bit like the six blind men in the Indian tale: different aspects of student work represent very different kinds of understanding. How to comprehend the overall student learning?

The National Academies of Sciences, Engineering, and Medicine has observed that its mission to improve “the understanding and application of science, engineering, and medicine toward the social, economic, and cultural well-being of the nation and planet” requires collaboration with the arts and humanities. NASEM is overseeing the publication of a consensus report examining evidence for the assertion “that educational programs that mutually integrate” artistic and humanistic learning with STEM learning lead to improved educational and career outcomes for students. In addition to examining “new models and good practices for mutual integration” of humanities, arts, and STEM, the report –expected to be published later this year-- will explore evidence of the value of integrating experiences and curricula from STEM, the arts, and the humanities and make recommendations for further work in this area [34].

However difficult to implement, the value of sound assessment of integrative curricular designs is hard to overstate. The impact of integrative courses on students and student learning must be understood in order to promote these experiments, understand their effectiveness, and encourage other engineering educators to adopt integrative learning assignments.

Our Experiment

In spring 2016, a transdisciplinary team of faculty at a small, primarily engineering institution offered a new two-term experimental course for first-year students. Taking a problem-based, project-based approach to undergraduate STEM education, this course would carry two course credits: 1000-level humanities credit and 2000-level engineering science credit. Our goal was to combine an introduction to the technical subject matter required of engineering students with the broad and integrated education known as liberal education. To be worthy of 2000-level engineering credit, we included adequate technical content and opportunities for students to apply that content in an open-ended engineering project. Adequacy of the content was determined by the engineering faculty involved in course design, instruction, and summative assessment of student work. These faculty came from the departments of Biomedical Engineering, Civil & Environmental Engineering, Chemical Engineering, and Mechanical Engineering. All had been involved in assessments of student learning outcomes for graduating seniors for the purposes of ABET accreditation. All of them were thinking about the kind of engineering content that would be appropriate for first-year students who needed to begin learning engineering design and specific engineering methods, principles, and content, and the integration of this knowledge with humanistic content and methods. To warrant the humanities credit, we included reading assignments from both the nineteenth and twenty-first centuries, determined in consultations between the engineering and humanities faculty. Both the humanists and the engineers were equally involved in course design, delivery, assessment, and redesign.

The first course consisted of a role-playing game modeled after the “Reacting to the Past” series of games that have become popular in humanities courses [35, 36, 37]. We asked students to understand historical urban contexts using material artifacts (atlases, city indices, fire insurance maps, census reports, and other government documents), and assigned historical readings about labor, urban life, immigration, and political discussions. Students frequently wrote responses to what they read, and in every case they learned about nineteenth-century [city name removed] through the lens of an actual historical person. In the second half of the course, students deepened

and applied their understanding of complex human and technical systems to real-world, current-day problems in waste management. In the second course, humanities content centered on readings, immersive activities and project work grounded in geography, sociology, religion, politics and international development. Students worked intensively in cross-disciplinary teams to scope problems and apply design thinking techniques that kept social factors such as financial, political, gender and power dynamics at the forefront of their project work. We have offered the course three times with the following course enrollments: 2, 17, and 9.

The technical content (listed in Table 1) consisted of introductory topics taken from several areas of engineering relevant to our wastewater treatment context. Students engaged them in a just-in-time fashion consistent with our integrated curricular design. We employed a variety of pedagogies: lecture, in-class demos, labs, historical and modern readings, calculation-based homework, and team projects.

The humanities content (listed in Table 2) consisted of the contextual understanding –through the disciplinary lenses of historical, philosophical, and literary study—of the time and place in which the technical content is implemented. Humanistic study provides not only disciplinary methods for research, interpretation, and communication –the methods of interrogation and rigorous thought— but also the capacity for more general insights into human needs and desires.

Table 1: Summary of Engineering Content	
Technical Topics	Content Covered
Conservation of Mass and Energy	Mass and Energy Balances in Continuous, Open Systems; Single and Multiple Units; Balances with Reactions -- Combustion.
Introduction to Fluids	Continuity and Bernoulli Equations, Fluid Properties & Statics Laminar vs. Turbulent Flow; Pressure Losses in a Pipeline
Materials	Introduction to Material Properties; Material Selection in Design
Separation Processes in Waste Treatment	Solid-Liquid Separations; Filtration Fundamentals; Pre-Treatment Techniques; Settling Rates
Statics	Equilibrium Equations & Force Analysis; Force, Displacement, Velocity, and Acceleration
Stress	Load Types, Deformation; Material Strength and Stiffness
Engineering Design	Importance and Challenges of the Design Process Defining the Problem; Introduction to Systematic Design

Table 2: Summary of Humanities Content	
Humanities Topics	Content Covered
Understanding and empathy for others	Close reading/listening (of texts, interviews, and other materials that represent particular human experiences) Writing assignments to promote insight into the emotional, cultural, & political factors that influence people's thoughts & behaviors
Appreciation for context	Reading, discussing, and debating texts and material artifacts from the historical and cultural contexts informing the class topic; Probing the social, historical, cultural roots of current events
Communication; capacity for civil & informed discourse	In-class role-playing that brings different voices & perspectives together in dialogue and debate; Individual & team writing assignments, including assignments advancing an informed argument in opposition to other arguments in the class
Research & Inquiry	Individual & team research assignments, culminating in a project report that includes attention to context and related approaches.
Reflection	Written and oral reflections on the experiences of taking different perspectives, learning from sources, listening to various stakeholders

Student Learning Outcomes

Defining specific and measurable learning outcomes for such an integrated course sequence is a challenge. For us, this continues to be a work in-progress. Certainly, we want students to begin to understand the global, economic, environmental, and social impact of engineering solutions. They should know how past histories and the challenges and opportunities they pose are relevant today and in the future. And, they should understand how science, engineering and humanities are critical for designs that solve sanitation problems. These learning outcomes might at first appear beyond what is attainable with first-year students. It is our belief they are not, and if the course design and assignments are scaffolded appropriately and suitable support is provided, we should expect students to achieve them at an elementary, but acceptable level. And, if early learners are successfully guided through this integrative learning experience, they are more likely to achieve a much higher standard later in the curriculum. We have evidence supporting this practice in our Great Problems Seminars. These integrated liberal arts/science courses have similar learning outcomes and have been an important part of WPI's first-year program since 2007 [28, 29, 33]. The GPS was an integral part of the evidence submitted and honored by the National Academy of Engineering with the Bernard Gordon prize in 2016 (<https://www.nae.edu/Projects/Awards/GordonPrize.aspx>). Additionally, other universities have demonstrated great success in integrative first-year courses or curricula. [30, 31, 32.]

These considerations led us to formulate the set of learning outcomes listed below. At the end of the course sequence, students should be able to:

1. gather and synthesize knowledge of the religious, political, moral, historical, economic, and cultural contexts in which technologies were invented and used;
2. identify, formulate, and solve engineering problems with understanding and sensitivity to their human and environmental context;
3. demonstrate and apply knowledge of mathematics, science, engineering;
4. acquire skills to function effectively on high-performing, diverse teams;
5. demonstrate empathy through designing technical interventions that demonstrate an appreciation of ethics, shared humanity, and the diversity of human experience as influenced by culture, race, ethnicity, gender, and class across different times and places;
6. conduct research into the history of a technological issue, finding, assessing, analyzing, interpreting, integrating and effectively using essential and appropriate primary and secondary sources, including quantitative and qualitative data;
7. design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, and sustainability;
8. present an argument in written, oral, and visual form that displays knowledge and understanding of the diverse history, culture, social geography, economic considerations, and technical details of a particular technical intervention;
9. examine issues with a mind open to a variety of reasonable positions and subject their own views to rational criticism;

10. contemplate multiple pathways of professional practice (graduate school, NGO, corporate) that would benefit from humanitarian engineering knowledge and skills (adapted directly from Lucena [38]).

Integrating STEM and Humanities: Example Assignments and Connections to Learning Outcomes

The first course in the two-course sequence is weighted more toward humanities content while the second course emphasizes engineering content. The net result is students receive three credit hours of humanities credit and three credit hours of general engineering credit. Throughout the sequence, assignments are placed in the appropriate context: 19th century Worcester in course 1 and the developing world (or equivalent) in course 2. Role-playing occurs only in course 1. All assignments include elements of both humanitarian and technical content; there is a mix of individual and team-based work; there are calculation-heavy assignments, reflective essays, historical readings, in-class activities, and capstone-like poster presentations and reports at the end of each course. Each assignment is designed to address at least one of our learning outcomes (LO), and instructor evaluations are based upon their assessment of the student work relative to those outcomes. Engineering-rich assignments focus on topics shown in Table 1 and connect directly LO 3. Their structure is fairly traditional (calculations and two introductory lab activities) and hence their evaluation is also traditional and is not described in detail here.

In the interest of space we describe four representative modules, two from each course, and their connection to our learning outcomes. We follow with a description of assessment instruments, a summary of student results and our evaluation of the assessment tools.

Course 1: Town Council Debate on a Proposed Sewage System for Worcester. This role-play involved a mock Worcester town council meeting where the city was to hear arguments for two different types of sewage transport and treatment. Two instructors, representing Col. George Waring and Dr. Rudolph Hering (both respected sanitary engineers of the time), played proponents of each option. All students were supplied relevant original documents for background including writings of both Waring and Hering. Two student teams were formed where, in character, each team took either the Waring or Hering position. Teams were given unique original material relevant to their position. The teams then debated the issue before the town council with council members played by instructors. A post-debate individual reflection assignment asked students to explain and justify their preparation process, identify all contextual factors that affected their choices; to reflect upon the whole activity, evaluate their own effectiveness, and think about improving their process in future open-ended assignments (assignment adapted from Delapp-Culver [26]). This assignment, readings, in-class debate, and post-reflection primarily addressed LOs 1, 6, and 8.

Course 1: Final Project. Again, we assigned students to teams and each was responsible for developing a proposal that would treat Worcester's sewage problem using one of three possible 19th century technologies: chemical precipitation, broad irrigation, or intermittent filtration. Deliverables were an in-character poster presentation and a final written report. Teams needed to set their proposed solution in the proper historical context, and provide the benefits and limitations of the design. Considerations also included the rapid population increase, some preliminary cost analysis, and recommendations for future steps. We designed the assignment to primarily address LOs 4, 5, and 6.

Course 2: Gender Analysis. Although the second course emphasized engineering content, that content was never separated from the human, social and cultural contexts. The final project,

described below, was the solution of a sanitary problem somewhere in the developing world or equivalent situation. We're no longer role-playing, but all the humanitarian issues introduced in course 1 are now transferred to a new context. A particularly relevant one is gender issues. The gender analysis assignment focused on each team's unique project and became part of their final report. This was a multi-step process with an initial individual analysis followed by a consensus-based team analysis derived from the individual analyses. Each step included class presentations, in-class active learning activities, and instructor facilitated draft reviews. The final gender analysis included how a team's proposed sanitation solution affects women and men; how gender dynamics affect decisions about sanitation (or other household or community); who has access to sanitation services or facilities; how different genders will interact/react to the team's proposed solution; whether the proposed solution is gender blind, gender aware or gender distributive; and how the proposed solution contributes to the empowerment of women and men. This module addresses primarily LOs 1, 5, 8, and 9.

Course 2: Final Project. As in course 1, a poster presentation and final report were required of each team. Teams researched specific locations and problems throughout the world, and submitted their choice to the instructors for final approval. Their project had to address some specific sanitation-related project in the developed or developing world. It must use quantitative and qualitative data in making its claims, and it must use perspectives from engineering and the humanities. In other words, it must be transdisciplinary and take a humanitarian approach to engineering. Each team was asked to:

- Identify a problem, and frame it in a way that it can be solved;
- Propose and evaluate several possible solutions before selecting one;
- Write a problem statement;
- Identify what is not known, decide on a methodology for learning more;
- Write an annotated bibliography;
- Conduct the research and develop a viable solution;
- Assess the pros and cons of the chosen solution *vis à vis* other solutions;
- Develop an assessment plan for the solution;
- Write a project report and design a project poster
- Present the project, explaining the problem and how the approach effectively addresses the problem.

Although the task is challenging, teams were guided through the multi-week process with a scaffolded instructional design that included in-class lectures and exercises, assigned readings, and frequent feedback from a faculty team with one humanist and one engineer assigned to each team. LOs 2, 3, and 7 were the focus of this project.

Approach to Assessment

Because the course was designed and is taught by a transdisciplinary faculty team with each class session deliberately integrating engineering and the humanities, our approach to assessment involved several challenging decisions. It was expected that to assess our integrated course as humanists and engineers working together, we brought both the strengths and limitations of our own disciplinary thinking. Certainly, any course should assess student mastery of disciplinary content. As a transdisciplinary teaching team, we each assessed the disciplinary content within our own expertise, often examining student work from the assignments we developed individually, using established methods of assessment: primarily, direct assessments of student work. However, how would we assess our student's cross-disciplinary cognitive skills, including the ability to

integrate knowledge from different disciplines? We found the AAC&U Value Rubric Development Project [19] quite useful, but not before deciding how to use its rubric for Integrative Learning (See Appendix 1) to assess students' knowledge. Which student artifacts would provide the best evidence of the various dimensions of integrative learning? Would we simply assess their homework, or would we set more ambitious (ungraded) assignments for the purpose of understanding how the course fostered integrative learning? Would we develop assessments to track their development during the course?

We approached these questions about assessment as we approached course design and pedagogy: by working together as a transdisciplinary team, explaining our disciplinary perspectives and values and putting them in conversation with those of colleagues from different disciplines. While taking an integrative approach to course design and pedagogy, we also consider integration an important student learning outcome, which granted us another reminder of how our different disciplinary trainings shape our understanding of what matters and why. In the end, our assessment measures were as diverse as the disciplinary content of the course itself.

Student mastery of disciplinary content was easy to assess through direct measures: the faculty who developed and taught a disciplinary class or assignment assessed student work individually, using established methods within their expertise. For the more integrative assignments, we relied on multiple reviewers, norming, and a consensus approach to grading. For the final reports, all instructors read all reports, then met to decide on grades through a collaborative process. In all cases, we reached consensus.

We based our assessment design upon standards of good practice: direct and indirect instruments, triangulation, and formative/summative applications of an array of instruments [39, 17]. Our design also drew directly from our own experience in other contexts that was heavily influenced by publications from our colleagues at Alverno College [40, 21]. Alverno's ability-based approach to learning and assessment provided extensive evidence supporting our application of similar instruments targeting our learning outcomes.

With each successive course offering, our curriculum design evolved and so did our assessment practices. We were constantly in a state of meta-assessment. For example, although we are obligated by university policy to use the standard course evaluation form, we found very early on that it is inappropriate for our learning outcomes and problematic since it assumes one instructor. That led us to use the customizable Student Assessment of Learning Gains instrument (<http://www.salgsite.org>). But, as we transitioned to more complex direct instruments as described below, this very useful instrument had to be set aside as students experienced assessment overload. If the six blind men were highly motivated to understand the elephant, the elephant itself was sometimes less than patient. We found that it doesn't like to stand still and be measured; it would rather run with the herd. Our challenge included finding ways to assess student learning that were also part of student learning.

Even given this challenge, we have retained some relatively short pre/post surveys. However, we've found, not surprisingly, that the richest information comes from direct measures. For illustrative purposes here, we'll focus on a few. For this paper we chose to concentrate on the instrument design, application in practice, and the evaluation of its effectiveness. This necessarily means we will deemphasize discussion of detailed student results. Some of those were previously reported [22, 23, 24, 25]. Since the course is being offered during this spring semester (2018), we will have more to say on results by conference time.

Archive of Student Work: At the end of the two-course sequence, student teams produce a report, a poster, and a prototype of their solution to a sanitation problem in the developing world. At least one engineering and one humanities faculty graded each report and presentation. Faculty agreed that the engineering evaluation is the easier one: Did students make the proper mass balance calculations? Did they properly size a composting toilet system for the given population? The more challenging part came as we attempted to determine students' level of understanding about the effect of their proposed solution on the community– be it social, financial, environmental, or political. We used various qualitative frameworks such as stakeholder analyses, gender analyses, and other evidence to ascertain the extent to which students achieved the outcomes stated above. Throughout the assessment work we relied on the AAC&U Integrated Learning Rubric [19]. Depending on the student evidence being evaluated we applied the appropriate dimensions and rated that evidence against four rankings using the rubrics shown in Appendix 1.

Reflective Essays: This type of assignment is ideal for capturing students' perceived understanding and for allowing them to process role-playing events and other class activities. Hence, reflective essays are useful as both a learning [41, 42] and assessment tool [18].

The mock town council assignment asked students to reflect on the project/presentation, and synthesize key components, in order to facilitate transfer of learning to other contexts. The reflections both showed us their process (and the extent to which it does integrate humanities & engineering) and also helped them with the metacognition necessary for effective transfer. Metacognitive approaches to learning, which help students be more aware of themselves as learners and actively review their learning strategies and resources [43, 44, 42], have been shown to increase the degree to which students will transfer their understanding to new situations without the need for explicit prompting [39].

We found that students demonstrated Milestone 2 level for dimensions of connections-to-discipline, transfer, and communication. Additionally, we found achievement of Benchmark and Milestone 2 for reflection and self-assessment. This preliminary analysis also suggested that students acquired a better understanding of, and appreciation for, effective team function.

Video Assessment: At the end of the spring 2017 course offering, we implemented a challenging direct assessment method. In a voluntary, ungraded, team-based event, we provided five teams of three students each a Dust Bowl-era photograph of a motherless family housed in a temporary encampment. We deliberately chose an image that represented a context that was distinct from those that students had considered during the course. By introducing an unfamiliar, obviously socially strained scene, and asking students to reflect on the situation and conditions apparent in the photograph, we were able to gain an understanding of how students transferred their knowledge to a new situation [9]. This assessment method was designed to reveal to what extent students developed and displayed a sense of social responsibility and an application of knowledge and skills to real-world (albeit historical) settings [2]. In this assessment, each team had approximately 30 minutes to respond in writing to several prompts designed to probe elements from our student learning outcomes such as empathy, humanitarian considerations, applications of technology (if appropriate), and sensitivity to context. We chose to videotape each team in order to probe team function. Recordings were transcribed, and a group of three instructors and an assessment consultant are currently analyzing the results. This instrument is modified version of the Verbal Protocol Analysis described by Chi [20] and later modified by Atman and Bursic [16]. We've used a similar process to assess early learning in chemical engineering [45, 15].

The design of this instrument was not simple and took several meetings with engineering and humanities faculty, in concert with our assessment consultant, to finalize the process. The evaluation team found reading transcripts and watching videos to be both illuminating and frustrating. Video analysis is complicated and time-intensive, occupying many person-hours for some of the teaching team. It was during these assessment meetings that we realized the utility of the AAC&U Integrative Learning VALUE rubric, which defines integrative learning as “an understanding and a disposition that a student builds across the curriculum and cocurriculum, from making simple connections among ideas and experiences to synthesizing and transferring learning to new, complex situations within and beyond the campus” (Appendix 1). The dimensions of connections-to-discipline, transfer, and communication are appropriate for analyzing evidence produced by teams during this session.

Although we rated connections and communication at Milestone 2 level, we expected better than benchmark performance for transfer. However, that was not the case. Perhaps the prompt was simply too unfamiliar since it was not directly related to sanitation. Another troublesome result was that while female teams recognized potential gender-based safety issues easily inferred from the photograph, male teams did not. This indicates to us a need for greater attention to gender analysis in future course offerings.

Our own meta-assessment of the video assessment tool revealed the need to modify it for the current course offering. We are now using the same photo and prompts, and are applying the instrument both pre- and post-course. We chose not to video record the team discussions due to the amount of work involved in analyzing video. Instead, on the first day of class, faculty observed ad hoc student teams while they completed the same tasks that had been required of students in the earlier iteration of the course. We witnessed adequate levels of student engagement and team performance. We will have much more to say about this evaluation by conference time since the post-course applications occurs at the end of April.

Scenario Analysis: In an effort to understand the presence and development of students’ understanding of the ethical dimensions of complex, socio-technical circumstances, we implemented an individual, in-class pre/post writing assignment. Students received a prompt that required them to analyze an industrial scenario in which a company was using an unreported and potentially toxic chemical. The scenario required students to ascertain technical factors such as accuracy of data, as well as ethical considerations, stakeholder interests, the risks of whistleblowing, broader issues related to social justice, and possible environmental racism. The pre-test prompts guided students to identify the salient issues and propose a course of action. The post-test prompt was given in the last week of the second term of the class. It asked each student to critique what they had written in the pre-test at the beginning of the course. Since this instrument did not require sometimes-tedious video analysis or long hours reading transcripts, it proved to be a low cost/high benefit assessment method. The post-test responses were more thoughtful and well-reasoned, and it was evident that students integrated ethics into the decision-making process. Furthermore, responses showed a heightened concern for the human aspects of the issue. It is significant that several students referenced specific class assignments as helpful in preparing them to consider these types of multi-dimensional situations. In addition, in two cases, student indicated that making moral, principled decisions was more important than allegiance to the company. Our summary evaluation is that students met Benchmark level for connections-to-experience, and Milestone 2 for connections-to-discipline, transfer, and reflection/self-assessment.

Global Study Applications

Finally, because our Learning Outcomes include understanding human contexts, we wondered whether our students could demonstrate transfer of knowledge from our course to their applications for study abroad. Our institution requires all students to complete a significant project experience, typically in their junior year, that must address a socio-technical issue. The project is multidisciplinary, not in a student's major field and is nearly always done in teams. Nearly 75% of our students complete this 9-credit hour project at one of our off-campus project centers. Currently we have more than 45 sites around the world where student teams and faculty advisors reside on-site for two months working full-time on projects generated by local sponsors. This Global Projects Program (GPP) is the oldest, most geographically extensive, and largest education abroad program in engineering in the US.

We are interested in probing how students' experience in our humanitarian engineering class from spring 2017 may affect their choice to apply to the GPP and if so, how their experience in our class was presented as relevant in their application and how their class experience affected the choices they made in their application, i.e. preference to work in the developing world, in underserved communities or in projects that highlight integrative learning. Students make decisions and submit applications to the GPP several months after the course ended. Thus, this assessment directly relates to our learning outcome (taken from Lucena) on "pathways of professional practice." Fortunately, implementing this indirect assessment is relatively easy, as we need only read the GPP applications from any of our course alumni and look for relevant text. We find the value of this assessment approach to be quite high because it clearly provides evidence for lasting effects from the course. Currently we have data on only five of our 17 alums. We are in the process of collecting applications from the remaining cohort.

These preliminary results are encouraging and evidenced by quotes from some of the applications:

"Understanding that an effective solution has to take into consideration the wants and needs of the people, not just the engineering behind it, is key in situations like this. The research that I completed, the work I put in, and the experience that I gained from Humanitarian Engineering will all be applicable and very beneficial to my International Qualifying Project."

"At first, I met this philosophy with skepticism, but as the course progressed I learned the importance and value of considering qualitative human factors before relying on the stone cold engineering. In essence, any engineering project is guaranteed to fail if the human needs of an individual are not carefully considered during the design process. I intend to practice this philosophy during my (GPP) project because I have first hand knowledge of its success and importance."

"This class changed the way I viewed engineering, engineering education, and what I want to do in my life. It emphasized the importance of cultural based thinking in engineering, which was not something I had really considered before."

"Mandi, India stood out to be my top choice....I would be of great use to the project team because of my (humanitarian engineering) class. We were in groups and had to fix sanitation issues in a location of our choice. We chose Varanasi, India and as a result I am very aware of the problems that modern India faces, as well as many social implications that could change engineering plans. Some of these situations that we dealt with when creating a toilet system for families in Varanasi were: unreliable power, scarce resources, safety of women, religion,... informing the community and much more."

Summary and Discussion:

Transdisciplinary integrated curriculum design is challenging and complex. Assessing the effectiveness of integrated curricula is even harder. We've demonstrated that an effective integrated course sequence combining humanities and engineering can be designed, delivered, and assessed. A variety of assessment instruments confirmed that first-year students can perform at a basic or higher level when presented with challenging learning outcomes, and when judged against a nationally accepted set of dimensions and rubrics. Continuous improvement allowed us to use our assessment results to improve future course offerings and to modify our assessment process to better understand student learning successes and deficits.

Our assessment process, like the course, is dynamic yet we can offer some conclusions based upon our work to date. We realize the elephant will keep moving, sometimes in predictable directions, and our team needs to move with it and attempt to guide it. As mentioned earlier, we preferred direct assessments because they produced the richest evidence for demonstrating achievement of learning outcomes. Project reports, reflective essays, in-class role-plays and presentations, and ungraded instruments like the scenario analysis and the video exercise provided opportunities for us to observe and measure the depth of student learning. The ungraded instruments also allow understanding how learning is or is not transferred to contexts slightly outside of the course focus. Detailed video and transcript analysis, while fascinating in understanding student discourse, just required too much time so we modified that instrument as described. Any evaluation requires rubrics and those produced by AAC&U (not just the integrated learning rubrics) were invaluable. We continue to use closed and open-prompt surveys but in a limited fashion. We found them valuable for understanding student attitudes and perceptions about the course, but less so for probing learning. In the end, the assessment portfolio is something that instructors must tailor to their context, learning goals, and local constraints. Everyone's elephant is unique!

Our challenge in assessing this course has mirrored the challenge of designing and teaching it: how do we harness our different experiences and disciplinary values without pitting them against each other? In the Indian fable, each man's perceptions of the elephant are both correct and limited. Like the AAC&U Value Rubric Development Project, which harnessed the expertise and efforts of teams of faculty and other education professionals from over 100 institutions of higher education, we have found that effective assessment of integrative student learning requires not only the perceptions and judgments of all of us, but also the conversations that help us interpret these perceptions and judgments to each other. The negotiations required to develop, teach and assess this integrated course involved weekly meetings and gave rise to a community of practice that has given as much to the faculty involved in it as to our students.

Like the blind men at the elephant, the humanists and engineers working on this project each bring the strengths and limitations of our own points of view, which is to say, of our disciplinary training. It has helped to have representatives of different disciplines in the same room, watching and discussing classroom dynamics and explaining to each other what we are seeing. In this way, we overcome the unrecognizably different perceptions of the blind men in the Indian fable. This is how transdisciplinarity works [46]: with the representatives of different disciplines explaining their different disciplinary methods to each other, so that a shared approach emerges at the intersections of disciplinary knowledge.

Appendix 1: “Integrative Learning” VALUE Rubric from the AAC&U

INTEGRATIVE LEARNING VALUE RUBRIC

for more information, please contact valuel@aacu.org



Definition

Integrative learning is an understanding and a disposition that a student builds across the curriculum and co-curriculum, from making simple connections among ideas and experiences to synthesizing and transferring learning to new, complex situations within and beyond the campus.

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

Dimension ↓	Rating →	Capstone 4	Milestones		Benchmark 1
			3	2	
Connections to Experience <i>Connects relevant experience and academic knowledge</i>		Meaningfully synthesizes connections among experiences outside of the formal classroom (including life experiences and academic experiences such as internships and travel abroad) to deepen understanding of fields of study and to broaden own points of view.	Effectively selects and develops examples of life experiences, drawn from a variety of contexts (e.g., family life, artistic participation, civic involvement, work experience), to illuminate concepts/ theories/ frameworks of fields of study.	Compares life experiences and academic knowledge to infer differences, as well as similarities, and acknowledge perspectives other than own.	Identifies connections between life experiences and those academic texts and ideas perceived as similar and related to own interests.
Connections to Discipline <i>Sees (makes) connections across disciplines, perspectives</i>		Independently creates wholes out of multiple parts (synthesizes) or draws conclusions by combining examples, facts, or theories from more than one field of study or perspective.	Independently connects examples, facts, or theories from more than one field of study or perspective.	When prompted, connects examples, facts, or theories from more than one field of study or perspective.	When prompted, presents examples, facts, or theories from more than one field of study or perspective.
Transfer <i>Adapts and applies skills, abilities, theories, or methodologies gained in one situation to new situations</i>		Adapts and applies, independently, skills, abilities, theories, or methodologies gained in one situation to new situations to solve difficult problems or explore complex issues in original ways.	Adapts and applies skills, abilities, theories, or methodologies gained in one situation to new situations to solve problems or explore issues.	Uses skills, abilities, theories, or methodologies gained in one situation in a new situation to contribute to understanding of problems or issues.	Uses, in a basic way, skills, abilities, theories, or methodologies gained in one situation in a new situation.
Integrated Communication		Fulfills the assignment(s) by choosing a format, language, or graph (or other visual representation) in ways that enhance meaning , making clear the interdependence of language and meaning, thought, and expression.	Fulfills the assignment(s) by choosing a format, language, or graph (or other visual representation) to explicitly connect content and form , demonstrating awareness of purpose and audience.	Fulfills the assignment(s) by choosing a format, language, or graph (or other visual representation) that connects in a basic way what is being communicated (content) with how it is said (form).	Fulfills the assignment(s) (i.e. to produce an essay, a poster, a video, a PowerPoint presentation, etc.) in an appropriate form.
Reflection and Self-Assessment <i>Demonstrates a developing sense of self as a learner, building on prior experiences to respond to new and challenging contexts (may be evident in self-assessment, reflective, or creative work)</i>		Envisions a future self (and possibly makes plans that build on past experiences) that have occurred across multiple and diverse contexts.	Evaluates changes in own learning over time, recognizing complex contextual factors (e.g., works with ambiguity and risk, deals with frustration, considers ethical frameworks).	Articulates strengths and challenges (within specific performances or events) to increase effectiveness in different contexts (through increased self-awareness).	Describes own performances with general descriptors of success and failure.

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