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Dr. Ralph Dusseau is a Professor of Civil and Environmental Engineering at Rowan University in Glassboro, New Jersey. Dr. Dusseau is also serving as the Associate Chair of the Department of Civil and Environmental Engineering and is Coordinator of the Engineering Management Programs at Rowan University. Dr. Dusseau was an Assistant and Associate Professor at Wayne State University in Detroit, Michigan from 1985 to 1995. Dr. Dusseau was the Founding Chair of the Department of Civil and Environmental Engineering at Rowan University from 1995 to 2008.

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Beena Sukumaran has been on the faculty at Rowan University since 1998 and is currently Professor and Chair of Civil and Environmental Engineering. Under her leadership, the Civil and Environmental Engineering Program has seen considerable growth in student and faculty numbers. Her area of expertise is in micro-geomechanics and has published over 100 peer reviewed conference and journal papers including several papers on engineering education and the unique undergraduate curriculum at Rowan University, especially the Engineering Clinics. She has been involved in various outreach activities to recruit more women and minorities into engineering and is Program Chair Elect of the Women in Engineering Division of ASEE. She is the recipient of the 2011 New Jersey Section of ASCE Educator of the Year award as well as the 2013 Distinguished Engineering Award from the New Jersey Alliance for Action.

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Introduction

When students enter higher education, they are receiving more than an education in a given discipline. They are presented with a chance to align their identities as it relates to their discipline. Acquiring knowledge from a higher education institution not only involves obtaining technical knowledge but also understanding how to navigate social and emotional elements of higher education [1]. Developing the social and emotional elements of higher education can help students understand where they fall within their discipline by making positive relationships with one another as well as relate to how their discipline is practiced [2]. Students who are not able to develop an alignment in a given discipline in higher education may change majors or drop out to seek a sense of belonging elsewhere.

Diversity is one of the greatest challenges to the engineering profession today. Many engineering schools struggle to attract and retain a student population that reflects the diversity of the general population. One of the key reasons cited for students leaving STEM is the perception of a chilly climate, especially by those who are members of underrepresented groups [3]. Furthermore, there is compelling evidence that diversity among students and faculty is crucially important to the intellectual and social development of both majority and minority students, and failure to create an inclusive environment for minority students negatively affects all students [4-6]. Recent research on diversity in engineering has shifted attention from traditional efforts to recruit and retain students from underrepresented groups, to ways of creating an inclusive environment through efforts such as curricular reform and instructional practice. For example, in a study on women in engineering, Knight, et al. [7] reported that engineering disciplines need to examine curriculum and instructional strategies to attract and retain a diverse student body and indicated that females and underrepresented minorities may gravitate toward or persist in disciplines that emphasize thinking from a broad systems perspective in which faculty link topics across disciplines [7].

This paper focuses on the Civil and Environmental Engineering (CEE) Department at Rowan University, where the overwhelming majority of students are white, male, and from middle class backgrounds. While this program has achieved a very high student retention rate within the discipline, previous efforts to increase diversity have been unsuccessful. The CEE Department has recently undertaken an ambitious effort to increase diversity using a multipronged approach. One of the strategies adopted by this department is to implement curricular changes that expose students to a wider palette of what civil engineering can be and who participates in the field. For this work in progress paper, the authors will showcase inclusive pedagogy and content at the course level. It is important to note that inclusion can take many forms, some of which require only a small effort but offer a potentially high impact. The authors would like to stress that the CEE Department is currently developing multiple ways to engage diversity with their students and no one particular path will be given preference.

There are times in which developing an inclusive curriculum can be seen as challenging [8] However, the perception of difficulty is no excuse to shy away from implementing a more inclusive classroom setting. ABET has included in its criteria for student development, a “respect for diversity", a recognition of how engineering has societal and global impacts, and an ability for continued self-improvement and learning [9] Having inclusive curriculum can help in creating a more diverse setting for students just by enabling different ideas and examples of engineering and engineers to be seen and discussed. Diversity helps students confront differences positively and ask questions [10]. Seeking information enables students to push their creativity and their ability to communicate with others [8, 10]. These are skills that lead to an ideal kind of engineering student.

Theoretical Framework

This work is framed in constructivist learning theory and critical pedagogy which have implications for inclusive curricula and instructional practice. Constructivism is based on the work of Piaget [11] with contributions from many other researchers and considers learning as an active process in which the learner builds conceptual understanding utilizing prior knowledge and experience and reflecting on those experiences. Critical pedagogy originated with the work of Friere [12] who promoted education as a practice of freedom that builds a partnership between teachers and learners, recognizes connections between individual experiences and context, and empowers learners to consider problems that relate to their own lives in order to pose new challenges and build new understanding.

In order to be inclusive, research-based instructional practices such as active learning, problem-based learning, and service learning, must be carefully designed not to reproduce conventional power structures within engineering [13]. For example, Riley and Claris [13] frame classroom inclusion in critical/liberative pedagogy in a way that supports the development of critical thinking, reflective judgment and epistemic transformations that challenge dominant power structures. Specific recommendations for practical implementation include collaborative problem solving in a space where it is safe to make mistakes, empowering students to bring prior knowledge and experience into the classroom and learning to claim authority, and exploring the people who made important contributions to the field (especially non-majority individuals). Mills, et al. [14] frame their work on gender-inclusive engineering within constructivist theory, focusing on the assumptions about prior experience and interest that are inherent in the curriculum, methods, classroom management and assessment.

In this work we adopt inclusive curriculum strategies in several courses in the Civil and Environmental Engineering curriculum at Rowan University. Many of the strategies will be adapted from the inclusive thermodynamics classroom described by Riley and Claris [15], and translated into the context of Civil and Environmental Engineering courses. The inclusion principles can be categorized as related to curriculum design (content, non-technical professional skills, assessment, and informal assumed knowledge) or teaching and learning (inclusive teaching methods, classroom interaction, laboratories and equipment use, and language and images) as described by Jost [16]. Our research questions are:

- What are the perceptions of the faculty regarding the inclusiveness of their class (before and after changes)?
- What are the perceptions of the students regarding the inclusiveness of the class (before and after changes)?

- In what way does the adoption of inclusive practices in a Civil and Environmental Engineering course influence student conceptions of engineering?

Methods

Faculty and student perceptions of inclusivity of the civil engineering curriculum will be measured using the Benchmarks for Cultural Change survey developed by Jost [16]. This survey was developed as a tool for assessing the inclusiveness of engineering courses and programs. While it was developed as part of a project for women in non-traditional areas of study, the survey can be easily modified to consider a more expansive concept of diversity. In fact, only one survey question mentions women specifically in the rating inclusive principles ("content that uses examples of applications relevant to their experiences and includes examination of *women's* interests and achievements"). The survey can be readily adapted to inclusion of all underrepresented groups.

Inclusion strategies are being piloted in several classes in the CEE curriculum and full implementation will begin in the 2017-18 academic year. The benchmark survey will be administered twice – once prior to the implementation effort, and again two years later. The survey will be completed by Civil engineering students and faculty. Survey responses for each aspect of an inclusive curriculum will be compared before and after implementation, as will the average of all responses, i.e., the "average level of inclusivity" used by Mills, et al. [14]. In addition, student and faculty responses will also be compared. The previous benchmarking done by Mills, et al. [14] using classrooms in the U.S. and Australia will serve as a basis of comparison.

Students' conceptions of engineering will be assessed using a concept map as described by [17]. Students in both the experimental and comparison groups of Freshman Engineering Clinic will complete concept maps at the beginning of their first semester and at the end of the course. The concept maps will be evaluated using a traditional scoring method [18] as well as content analysis [19]. The traditional scoring method is based on the average numbers of concepts, crosslinks, hierarchies, and highest hierarchy. Barrella, et al. [19] have previously coupled a traditional scoring method with content analysis to provide a more complete understanding of how students' perceptions of engineering decision-making change from the beginning to the end of a course. In this study we will employ a similar approach to identify prevalent themes and to track the changes in students' perception of engineering between the beginning and the end of the course.

Setting the Tone on the First Day of Class

Civil and Environmental Engineering faculty at Midsized Northeastern University have implemented several inclusive classroom strategies in their courses. There are relatively low-level means of being inclusive that can be done on an individual level. Simply acknowledging that differences exist between student identities can help pave the way for more inclusion [10]. A simple way to acknowledge differences is by adding a welcoming diversity statement in a course syllabus. AT Rowan University, several CEE faculty have elected to adopt the diversity statement below, which goes beyond a nondiscrimination statement to reflect the faculty member's core value of inclusion and readiness to disrupt bias and discrimination:

> "I am committed to creating an inclusive environment in which all students are respected and valued. I will not tolerate disrespectful language or behavior on the basis of age, ability, color/ethnicity/race, gender identity/expression, marital/parental status, military/veteran's status, national origin, political affiliation, religious/spiritual beliefs, sex, sexual orientation, socioeconomic status or other visible or non-visible differences."

The importance of the first sentence of this statement should not be overlooked. This goes beyond the sometimes mandatory nondiscrimination statement to express a true commitment to welcoming and respecting students. It is important that the faculty member who includes a statement like this be prepared to interrupt any incidents of bias or disrespect that arise during the semester. Another promising practice for the first-day-of-class is to offer students the opportunity to self-identify through their names or pronouns. This helps set up a classroom environment where students feel more comfortable and welcome. One faculty member at Rowan University learns more about her students' personal identities by using a poem activity to learn more about the students, including their family background and important holidays. The faculty member also shares her background as an ice breaker activity.

Introductory Engineering Course

There are more course-oriented ways to incorporate diversity. Within a student's undergraduate career, certain courses can explore engineering in the broader context. At Midsized Northeastern University, the introductory engineering course was redesigned to introduce topics such as the history of technological innovations, profiles of important innovators, engineering and social justice, and engineering ethics. The instructor framed the discussions around societal and cultural intersections with engineering, providing an opportunity for in-class discussion of issues that students find important to engineering. For example, one of the authors of this paper uses lecture time to discuss how different engineering disciplines evolved over time. Historic and non-western examples were used to highlight elements of engineering that expand students' conception of the profession, while local examples drew students into issues that might directly impact their own lives. The course also highlighted the contributions of engineering professionals and pioneers who are from underrepresented groups, with the aim or helping students to develop a sense of belonging and identity within their discipline.

Projects in introductory courses and throughout the curriculum can challenge students to consider the impacts of engineering and what counts as engineering. One CEE Faculty member developed a project for the introductory engineering course that challenges students to consider the implications of their engineering design and actions in different cultural contexts. This project explored how algae farming can be used to improve the economy and welfare of a given country or community. This project demonstrated how an engineered system is shaped by a context of different culture and help students come up with novel means to solve issues [9].

Environmental Engineering

Environmental Engineering is a core course in the CEE curriculum. The inclusive practices implemented in this course are based on the recommendations of Riley and Claris [15]. The inclusive Environmental Engineering course covers the traditional core technical topics and establishes the typical base of skills and knowledge required in the discipline; technical objectives align closely with those in a traditionally-taught course. However, the course has additional criteria such as:

- Knowledge of the historical context in which Environmental was developed as a field in western science, as well as knowledge of nonwestern technologies
- The ability to apply Environmental Engineering to everyday life
- The ability to think critically about Environmental Engineering and engineering ethics and societal impact

The assessment of student learning has been aligned with the goals of liberative pedagogies. While traditional assessments can still be used in an inclusive class, additional assessments were designed to measure students' abilities to think critically and to apply the course material to everyday life. Below are three examples of inclusive assessments, related to ethics, nonwestern water resources technologies, and applications of water resource engineering to everyday life:

Example 1: Ethics Assignment: *Many of America's hydropower dams were built in the early part of the 20th century. The cumulative impacts of multiple hydropower dams are often much greater than the simple sum of their direct impacts. Even a very small single dam can entrain fish, block fish passage and displace wildlife. A series of dams can severely impact an entire watershed, even if each of the individual dams seems relatively low impact when considered in isolation. The biggest dam removal project in history in now well underway in Olympic National Park in Washington State where two century-old dams along the Elwha River are coming out. The Elwha river dams originated in the mind of entrepreneur Thomas Aldwell, who envisioned power plants to fuel the local economy and run a paper mill. When Aldwell built the Elwha Dam, Native Americans were not considered U.S. citizens.*

- *What is the human toll (The Klallam Native American Tribe) from the dam construction?*
- *How is the ecosystem harmed by construction of dams?*
- *Why were the Elwha Dam and the Glines Canyon Dam removed in Washington state?*
- *How is this scenario very similar to other major water resources projects around the world?*

As recommended by Riley [3] the ethics assignments evaluates writing quality, critical thinking and analytical skills, the ability to consider more than one ethical perspective, structured argumentation, and creativity.

Example 2: Nonwestern assignment: *Arsenic contamination in Bangladesh is a hot political issue both at home and abroad. The class will have to investigate the politics behind how the contamination has become more widespread due to efforts of the World Bank and its Shallow tube well project. The World Bank project was aimed at providing safe drinking water to Bangladeshis and to decrease the infant mortality rate, but it has led to the mass poisoning of millions of poor people. The ethics component is interesting – water quality studies were absent during the intense shallow tube well project. Bangladesh currently has a very rudimentary environmental regulatory agency.*

- *Were the World Bank and other local and global agencies responsible for water quality investigations?*

- *Analyze the ethical implications of providing drinking water without testing the water quality. Does your analysis change depending on the ethical viewpoint from which you analyze the situation?*
- *Would this crisis have occurred if the existing technology was being provided to a rich developed nation?*
- *What technical changes have to be made to provide the people of Bangladesh safe drinking water?*

The assignment on nonwestern water resource technology evaluates writing quality, technical considerations, critical thinking, reflective thought and creativity.

EXAMPLE 3: Water Resources in Everyday Life: *The average American family uses more than 300 gallons of water per day at home. Roughly 70 percent of this use occurs indoors. With depleting freshwater sources and droughts what personal habit changes and technological inventions as an engineer can you suggest to sustain the water resources in the USA?* The assignment relating water resource engineering to everyday life evaluates writing quality, technical considerations, creativity, and reflective thought and reflective action (praxis).

Future Work

Certain courses present more challenging situations for developing inclusive content. Structural Analysis is a required junior-level course in the CEE Department at Rowan University. As a junior- and senior-level design courses in structural engineering, this course has a heavy emphasis on technical content, and at first glance it appears to offer fewer opportunities to introduce engineering in a social context than a course such as water resources. As a first step toward inclusive practices in this course, in the spring 2017 semester, inclusive pedagogical practices are being adopted to promote student engagement. In-class, team problem solving will be implemented using inclusive approaches that make it safe for students to make mistakes.

The next steps toward making Structural Analysis more inclusive is to develop inclusive content. Examples will be curated of noteworthy buildings or structural elements from different times and cultures so that students can have an opportunity to be critical about how their knowledge can be applied. For instance, arches were used in ancient civilizations and have been part of architectural tradition for about 4,000 years. Bringing in examples from ancient civilizations around the world helps decenter western civilization and allows students to explore the intersection of their technical and historical knowledge. It is a simple exercise for students to find examples of modern-day arches used in structures in their local communities, and this helps students to connect concepts to everyday life. Examples will also be drawn from structures built by humanitarian organizations such as Engineers without Borders, Habitat for Humanity, and Canstruction. Examples of structural failures also present opportunities for exploring structural analysis in a societal and often ethical context and will be added in fall 2017. These case studies will be discussed by student teams and then each team will be asked to comment on the reasons for the failure and how the failure could have been prevented. The subjects of these case studies will include structural failures worldwide, especially in third world countries. In addition, the student teams for the course (for both discussions and problem-solving) will be selected to be as diverse as possible so that a variety of student perspectives can be brought to the discussions on structural failures and problem solving.

In the junior level Transportation Engineering course, a faculty member introduced a project in the spring 2017 semester that uses several inclusive practices. The goal of the project is to develop creative solutions for transportation problems. Students working in groups of 3-4 (based on schedule, GPA and student choice) identify a transportation safety problem in a country other than the US, UK, and Canada, and develops an implementable solution for that problem. Thus, in developing the solution to a technical problem students must consider the global context in which it is to be implemented. The project deliverable is a 2-minute video that effectively demonstrates the problem and presents the solution. The audience includes individuals of all ages. The nontraditional deliverable expands the repertoire of assessments used in the class and expands the range of specific skills that are used in that assessment. In this learner-centered approach to a class project students share the responsibility for learning and are empowered as authorities on their specific transportation problem.

Inclusion can also go beyond course content to assessment practices. Testing and rubric grading can be good assessments for students and their work, but other forms of assessment may show evidence for growth. Blogs and other reflections could help assess student progress [20]. As the CEE Department increases its commitment to diversity and inclusion, the faculty will strive to discover multiple avenues to improve the current curriculum.

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References

[1] S. Hooker and B. Brand, " College knowledge: A critical component of college and career readiness.," *New Directions for Student Leadership,* vol. 127, pp. 75-85, 2010.

[2] A. Dymnicki, M. Sambolt, and Y. Kidron, "Improving college and career readiness by incorporating social and emotional learning," *College and Career Readiness and Success Center,* 2013.

[3] The President's Council of Advisors on Science and Technology, "Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics.," 2012.

[4] P. Gurin, "The expert report of Patricia Gurin," 1998.

[5] R. D. Reason, B. E. Cox, B. R. L. Quaye, and P. T. Terenzini, "Faculty and institutional factors that promote student encounters with difference in first-year courses.," *Review of Higher Education,* vol. 33, pp. 391-414, 2010.

[6] H. Smith, R. Parr, R. Woods, B. Bauer, and T. Abraham, "Five years after graduation: Undergraduate cross-group friendships and multicultural curriculum predict current attitudes and activities," *Journal of College Student Development,* vol. 51, pp. 385-402, 2010.

[7] D. Knight, L. R. Lattuca, A. Yin, G. Kremer, T. York, and K. Hyum, "An exploration of gender diversity in engineering programs: a curriculum and instruction-based

perspective.," *Journal of Women and Minorities in Science and Engineering,* vol. 18, pp. 55-78, 2012.

[8] K. Phillips, "How diversity makes us smarter," *Scientific American,* 2014.

[9] ABET. (2016). *Criteria for Accrediting Engineering Technology Programs, 2016-2017*. Available: http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-technology-programs-2016-2017/ - curriculum

[10] M. Sapon-Shevin, *Widening the circle: The power of inclusive classrooms*. Boston: Beacon Press, 2007.

[11] B. J. Wadsworth, *Piaget's theory of cognitive and affective development: Foundations of constructivism*, 5th ed. White Plains, NY: Longman Publishing, 1996.

[12] P. Friere, *Pedagogy of the Oppressed*. New York: Seabury Press, 1968.

[13] D. M. Riley and L. Claris, "From persistence to resistance: pedagogies of liberation for inclusive science and engineering," *International Journal of Gender, Science and Technology,* vol. 1, pp. 36-60, 2009 2009.

[14] J. E. Mills, M. Ayre, and J. Gill, "Gender inclusive curriculum in engineering and construction management," Australian Learning and Teaching Council, Ltd., Melbourne2012.

[15] D. M. Riley and L. Claris, "Pedagogies of liberation in an engineering thermodynamics class," in *American Society for Engineering Education Annual Conference*, 2003.

[16] R. Jost, "Benchmarks for Cultural Change in Engineering Education," University of Newcastle, Newcastle2004.

[17] Ü. Kőycű and M. J. de Vries, "What preconceptions and attitudes about engineering are prevalent amongst upper secondary school pupils? An international study," *International Journal of Technology and Design Education,* vol. 26, pp. 243-258, 2015.

[18] J. Gerchak, M. Besterfield-Sacre, L. J. Shuman, and H. Wolfe, "Using Concept Maps for Evaluating Program Objectives," in *ASEE/IEEE Frontiers in Education Conference*, Boulder, CO, 2003.

[19] E. Barrella, J. J. Henriques, and K. G. Gipson, "Using Concept Maps as a Tool for Assessment and Continuous Improvement of a First-Year Course," in *American Society for Engineering Education Annual Conference*, New Orleans, 2016.

[20] D. M. Riley, L. Claris, N. Paul-Schultz, and I. Ngambeki, "Learning/Assessment: A tool for assessing liberative pedagogies in engineering education," in *American Society for Engineering Education Annual Conference*, 2006.