# *Using Concept Mapping to Develop Inclusive Curriculum*

Stephanie Farrell, Cheryl Bodnar, and Tiago Forin
Rowan University
Glassboro, United States

***Abstract*—This is a Work-in-Progress paper that will explore how concept maps can be utilized to make engineering curricula, pedagogy, and assessment more inclusive. Making engineering more inclusive is one method in increasing the representation of women, underrepresented minority (URM) students, and underserved populations in an engineering program. The paper will show how inclusive curriculum, pedagogy and assessment was developed over time. It is important to understand the historic development of inclusive curriculum in order to understand how concept mapping can be used to enhance inclusivity as well as student learning and development. After showing how concept mapping can be used, future work and development will be described to show what will develop over time.**

***Index Terms*—Concept mapping, inclusive curriculum, pedagogy, assessment.**

## I. Introduction

In the Civil and Environmental Engineering Department at Rowan University, an ambitious plan for curricular and extracurricular reform is being used to increase the representation of women and underrepresented minority (URM) students as well as groups that have been underserved by traditional efforts to increase diversity. Our multi-pronged approach includes revising admission criteria; enhancing the perception and understanding of diversity and equality; developing a mentoring program for first year and transfer students; providing role models to enrich aspirations for all students; and transforming the existing approach to civil engineering education to be more inclusive of all students.

An inclusive approach to engineering education aims to make engineering accessible, relevant and engaging for all students [17]. With equity and fairness at the core of inclusive education, it is essential to consider and value students' differences through curriculum, pedagogy and assessment [6]. The diversity in student learning styles, life experiences, and talents can influence how they perceive topics covered in courses. This Work-in-Progress paper explores the role of concept maps in making engineering curricula, pedagogy and assessment more inclusive.

## II. Inclusive Curriculum, Pedagogy and Assessment

This work is framed in cognitive constructivist learning theory and critical pedagogy which have implications for inclusive curricula and instructional practice. Constructivism is based on the work of Piaget (in Wadsworth) 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 [19]. Piaget's theory is based on the principle that all cognitive development progresses towards increasingly complex and stable levels of organization, and new information is assimilated into existing cognitive structures and accommodated through the formation of new cognitive structures [19]. A detailed treatment of the theory underlying concept mapping is provided by Novak and Cañas [9]. Critical pedagogy originated with the work of Freire 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 [5]. Mills et al. 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 [7].

Inclusive curricular content is designed to be relevant and engaging for students from diverse backgrounds. Curricular changes can take a variety of forms including the use of examples that relate coursework to everyday life, demonstrate contributions of diverse individuals to engineering, or decenter western civilization [11]. The connection to social relevance is also at the core of liberative pedagogy [11]. Inclusive pedagogy requires careful implementation of research-based instructional practices such as active learning, problem-based learning, and service learning, such that conventional power structures within engineering are not reproduced [12]. For example, Riley and Claris 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 [12]. 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).

Inclusive assessment considers the greater diversity of learning outcomes that are inherent to inclusive curriculum and

978-1-5090-5920-1/17/$31.00 ©2017 IEEE

inclusive pedagogy. Riley et al. describe an inclusive assessment tool that both measures and enhances student learning, encourages reflection and critical thinking, and allows students to connect classroom content with their personal experience [11]. Studies have also shown that when the stereotype threat is taken away during exams, women and URM students do as well as the majority population students [15, 16]. Using a variety of assessment methods ensures that specific students are not advantaged or disadvantaged by specific forms of assessment [3]. Varying assessment activities offers the advantage of helping to develop a broader range of interpersonal and professional skills [3].

## III. Concept Mapping as a tool for creating inclusive Curricula, pedagogy, and assessments

Concept maps are graphical tools that can be used to represent the connections among a collection of concepts. In a concept map, the nodes represent concepts associated with the content area and the arcs or lines represent the relationships that exist between these concepts [18]. Concept mapping has been used for a variety of different purposes within STEM education. For instance, concept mapping was previously studied as a means to determine if young students can understand abstract concepts in science [9]. In this study, it was observed that students could explain scientific concepts by taking the time to see how individual ideas in a broad topic related to one another [9]. It was also determined that current preconceptions the students were bringing to the classroom were important and heavily influential to the learning process that was taking place [2, 9].

As we are interested in investigating how concept mapping can make engineering curricula more inclusive, it is important to see how inclusive practices can be applied to concept mapping. One of the ways to make coursework more inclusive is to determine students' prior knowledge and relate this to their coursework. Concept maps can be used to achieve this goal as they can provide the instructor with a level of understanding of what the students' conceptual knowledge of a topic is and they can provide a visual representation to students of how a new topic links back to their prior knowledge of the field. Pierre-Antoine et al. applied concept maps in this manner when they sought to use them to improve the curricula of a mechanics course [10]. For instance, through analysis of the student maps they identified that "moments" were often left separated from other terms associated with the course. This led the authors to changing the structure of the course to put an increased emphasis on "moments" and how they connect back to the course material. They also found that ethics didn't often appear in student maps and chose to more clearly integrate this content in future iterations of the course [10].

Concept maps support inclusive pedagogy as they allow students to have autonomy in their learning. Calvo et al. used an electronic software to help assist students in the generation of their concept maps [4]. Unlike other concept mapping activities, students in their class were given three week period to work on their concept maps and could reach out to the instructor as needed. After this time, they were provided the opportunity to generate maps collaboratively in groups of 2-3. The results from their study demonstrated that students felt the electronic concept mapping tool was useful for learning and that the opportunity to work on the maps collaboratively was particularly enriching [4].

Concept maps most commonly are applied within engineering education as a means of assessment for student learning, thereby adding variety to the types of assessment used in the class [2, 18]. In addition to providing information about student understanding in a particular content area, concept maps round out information provided by other assessment methods such as tests and reports. By requiring students to create multiple concept maps, faculty can visually see how the students' personal comprehension of the concept is expanding and being refined across time. Student concept maps also provide faculty with information about the creation and retention of misconceptions and can help guide students to more effective development. Thus, faculty can use the concept maps to identify areas of misconception or gaps in connections, and they can use this information for iterative refinement of the class material to emphasize missed concepts. Barrella et al applied this approach to concept mapping when examining the change in student perception of engineering decision making within their first-year engineering course [1]. They found that students may have a more in depth view of how engineers make decisions after their participation in the course and that they also were able to incorporate new terms associated with decision making by the end of the course [1]. Another example of using concept maps to measure changes in student understanding of a content area was done by Roberts et al in their civil engineering course [14]. They observed that over the course of the semester there was an increase in the number of infrastructure components identified and a statistically significant difference in the number of infrastructure sectors included within student's concept maps.

## IV. Future work

We will determine how well concept maps can be used to create inclusive curricula, pedagogy and assessments through their use within a first-year engineering hands-on multidisciplinary project-based course. The course selected includes a project that examines how algae farming, harvesting, and refinement can address global challenges to engineering. For this reason, we selected to use a concept map focused upon "engineering in a global context" to determine how students see the role of an engineer in terms of what disciplines inform practice, what populations engineers impact, what industries engineers may work for and any other concepts they feel are important in their viewpoint of the engineer in a global context. Students will be guided through a concept map training exercise to help scaffold them through the process of what is involved in generating a concept map. This is important because it provides the opportunity for faculty to explain the reasoning behind the concept map and give an example on how to relate ideas together [2]. They will then complete a concept map using the prompt provided at both the beginning and the end of the semester. The concept maps created by students at the start of the semester will be reviewed and analyzed using two different scoring methods - a holistic approach using an integrated scoring rubric and a traditional scoring method [1, 2]. There are benefits and drawbacks associated with each of these approaches to scoring the concept maps.

The holistic approach has been observed to provide better capabilities at identifying differences in student knowledge, breadth, depth and overall quality relevant to the central topic although it can be more difficult for obtaining strong inter-rater reliability due to subjectiveness of the judging of each of the rubric elements. The traditional approach is much less time intensive and has higher ability for consensus among judges as it is based on the average numbers of concepts, crosslinks, hierarchies, and highest hierarchy but may not provide the same level of detailed understanding [20].

Once the concept maps have been scored it will be possible to determine students' prior knowledge associated with engineering in a global context and potential misconceptions they may have. The curricula within the course can then be modified as necessary to openly address misconceptions in class and then the final concept map exercise can be used to observe if the students have retained the correction. The results from the concept maps can also be discussed with students throughout the course to help them with developing an understanding for how new concepts that are being introduced can integrate with their prior knowledge. Finally, upon scoring of the post-concept maps and making comparisons of differences between the maps from the beginning and the end of the semester it will be possible to determine how effective the concept maps were at providing an inclusive assessment tool that rounds out the other forms of assessment being completed on the project.

## ACKNOWLEDGMENT

This material is based upon work supported by the National Science Foundation under IUSE/PFE:RED Grant No. 1632053 and EEC IUSE 1610164. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

## REFERENCES

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

[2] Besterfield-Sacre, M., Gerchak, J., Lyons, M. R., Shuman, L. J., & Wolfe, H. (2004). Scoring concept maps: An integrated rubric for assessing engineering education. *Journal of Engineering Education*, *93*(2), 105-115

[3] Brown, S. and Glasner, A. (2003). Assessment Matters in Higher Education: Choosing and Using Diverse Approaches. Third edition. Buckingham: Society for Research into Higher Education and Open University Press.

[4] Calvo, I., Arruarte, A., Elorriaga, J.A., Larranaga, M., Conde, A. (2011). The Use of Concept Maps in Computer Engineering Education to Promote Meaningful Learning, Creativity and Collaboration. 41st ASEE/IEEE Frontiers in Education Conference, Rapid City, SD, October 12-15, 2011.

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

[6] Hockings, C. (2010). Inclusive learning and teaching in higher education: a synthesis of research. Evidence Net. Higher EducationAcademy.https://www.heacademy.ac.uk/system/files/inclusive_teaching_and_learning_in_he_synthesis_200410_0.pd. Accessed 29 April 2017.

[7] Mills, J.E., Ayre, M., and Gill, J. (2012). Gender inclusive curriculum in engineering and construction management. Australian Learning and Teaching Council, Ltd., Melbourne.

[8] Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of research in science teaching*, *27*(10), 937-949.)

[9] Novak, J. D. & A. J. Cañas, The Theory Underlying Concept Maps and How to Construct and Use Them, Technical Report IHMC CmapTools 2006-01 Rev 01-2008, Florida Institute for Human and Machine Cognition.

[10] Pierre-Antoine, R., Sheppard, S.D., Schar, M. (2014). Utilizing Concept Maps to Improve Engineering Course Curriculum in Teaching Mechanics. 121st ASEE Annual Conference Proceedings, Indianapolis, IN, June 15-18, 2014.

[11] Riley, D. (2008). Engineering and social justice. *Synthesis Lectures on Engineers, Technology, and Society*, *3*(1), 1-152.

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

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

[14] Roberts, M.W., Haden, C., Thompson, M.K., Parker, P.J. (2014). Assessment of Systems Learning in an Undergraduate Civil Engineering Course using Concept Maps. 121st ASEE Annual Conference Proceedings, Indianapolis, IN, June 15-18, 2014.

[15] Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of personality and social psychology*, *69*(5), 797.

[16] Steele, C. M., Spencer, S. J., & Aronson, J. (2002). Contending with group image: The psychology of stereotype and social identity threat. *Advances in experimental social psychology*, *34*, 379-440.

[17] Thomas, L. & May, H. (2010). Inclusive learning and teaching in higher education. York: Higher Education Academy.

[18] Turns, J., Atman, C. J., & Adams, R. (2000). Concept maps for engineering education: A cognitively motivated tool supporting varied assessment functions. *IEEE Transactions on Education*, *43*(2), 164-173.

[19] Wadsworth, B. J. (1996). *Piaget's theory of cognitive and affective development: Foundations of constructivism*. Longman Publishing.

[20] Watson, M.K., Pelkey, J., Noyes, C.R., Rodgers, M.O. (2016). Assessing Conceptual Knowledge Using Three Concept Map Scoring Methods. Journal of Engineering Education, 105(1), 118-14.