A Case-Study Approach to Interlink Humanities with Engineering Education

Dr. Ravi T. Shankar, Florida Atlantic University

Ravi Shankar has a PhD in Electrical and Computer Engineering from the University of Wisconsin, Madison, WI, and an MBA from Florida Atlantic University, Boca Raton, FL. He is currently a senior professor with the Computer and Electrical Engineering and Computer Science department at Florida Atlantic University. His current research interests are on K-12 education, engineering learning theories, and education data mining. He has been well funded by the high tech industry over the years. He has 7 US patents, of which 3 have been commercialized by the university. This research work is a collaboration with the Children’s Services Council of Broward county in FL.

Dr. Diana Mitsova, Florida Atlantic University

Diana Mitsova has a background in research design, statistical and spatial analysis, as well as environmental planning and modeling using geographic information systems, and interactive computer simulation. Her primary area of research involves the impact of urban development on ecosystems and other environmentally sensitive areas. Her recent publications focus on the impact of climate-related stressors on coastal communities and the implementation of planning approaches related to enhancing coastal resilience to natural hazards. Her research has been funded by the National Science Foundation, National Park Service through FAU Environmental Sciences Everglades Fellowship Initiative, USGS, and The Nature Conservancy.

Dr. Alka Sapat, Florida Atlantic University

Alka Sapat is an associate professor of public administration at Florida Atlantic University. Her research interests include disaster and crisis management, environmental policy and justice, federalism, and social networks analysis. She was a Research Fellow with the National Science Foundation’s “Next Generation of Hazards Researchers” program and has been involved in a number of initiatives including NSF funded projects on topics of building code regulation, disaster-induced population displacement, and the role of diasporas in disaster recovery and resilience. Her work has been published in the Natural Hazards Review, Public Administration Review, the International Journal of Mass Emergencies and Disasters, and other scholarly venues. Sapat’s teaching interests include disaster management and homeland security, disaster planning and public policy, research methods, and statistical analysis. She serves on the Florida State Disaster Housing Task Force and the Governor’s Hurricane Conference committee, along with serving on local committees on post-disaster housing initiatives.

Mr. David J. Terrell, Florida Atlantic University

Mr. David Terrell earned a Master of Science in Computer Science from Florida Atlantic University in 2015 and has worked within the Engineering field since completing his degree. The objective of Mr. Terrell’s graduate research was to identify socioeconomic demographic risk factors impacting the life chances of minority groups within 100 of the top populated metropolitan areas in the USA.
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Abstract:

We have developed an executable case-study approach to expose engineering students to social and community issues. Undergraduate engineering students can team up with social science students to identify, analyze, and potentially solve such issues. We hypothesize that this will not only increase social awareness among mainstream engineering students, but also pave the way to recruit and retain women and underrepresented minority students in engineering.

Background:

This paper’s initial focus was on creating greater opportunities and preparation for engineers to engage in interdisciplinary endeavors, as related to complex sociotechnical systems. Engineers first need to become aware of the societal needs and their various influencing factors, before they can apply their problem solving skills to improve the status-quo. Engineering students, accustomed to working with well-defined problems, may be baffled by the ambiguity and uncertainty in social and community issues. Social science students, on the other hand, are trained to make sense out of ill-defined problems. Thus, teaming up students from these two different backgrounds can help identify and solve (perhaps iteratively) societal challenges.

Framing as above, based on typical engineering and social student traits, and questioning this framing, led us to a very different perspective, that of helping under-represented minority (URM) and female students in engineering to find a common cause to continue to be affiliated with engineering. In other words, this approach might also help improve retention and graduation of these groups (URM and women) in engineering, while also improving recruitment opportunities among these groups in the longer run. Support for this perspective comes from social study research that working with real-world and narrative problems might help these students to embrace better their identity as engineers.

To facilitate such collaboration, we (three faculty members from engineering and social sciences) will teach concurrent courses for students in our disciplines, and bring our students together during the semester to interact and collaborate. Each team of 4 students will be assigned a case study to discuss, collect data on, and analyze by conducting what-if analysis. Since our engineering course will be an elective course, it may attract predominantly URM and women students because of this case-study focus. Our desire to incorporate state-of-the-art tools may also facilitate the recruitment of mainstream engineering students. Thus, it will be a healthier mix, typically found in other disciplines, such as medicine, nursing, business, biology, and social sciences.
We have developed a specific application to showcase the flow to our students. For this we examined the top 100 US metropolitan statistical areas (MSAs) for socio-economic demographics of four racial/ethnic groups and corresponding police-initiated homicides. Data for this came from federal, state, and county agencies, as well as non-governmental organizations. A J48 – decision tree algorithm written in Python was used to compare data across different races and ethnic groups for factors that predicted such homicides. One can compare the various trade-offs made in various MSAs and their impact on quality of life metrics, to find multiple alternative hypotheses to pursue, and find ways, both engineering and non-engineering, to improve such metrics. This should help place engineering solutions in the broader scope of things and their impact.

We hypothesize that, by providing scaffolding with 'executable' narrative case studies and interaction with students in other disciplines, we can help mainstream engineering students to step out of their comfort zones and reflect on broader societal issues. We also hypothesize that this would help non-mainstream engineering students to find a new awareness and strength in becoming engineers.

Our approach is derived from two theoretical models with strong emphasis on student involvement in the learning process: active student engagement (ASE) and project-based learning (PBL). Both approaches assume active student participation in learning practices where exchange of ideas, extensive collaboration, and interdisciplinary synergies are essential. We will also leverage two pedagogies: scaffolding students in their metacognition process to become self-directed learners; and creation of a teaching program based on case discussion pedagogy.

We expect to offer our courses during and after spring 2018. We will use pre and post surveys to measure improvements, if any, in students’ team skills, social awareness, and the metacognition process. Other formative, summative, and longitudinal studies are also planned.

Rationale:

STEM Pipeline Challenges:

Recent push to increase enrollment, retention, and graduation of STEM graduates has led to many research studies to identify the characteristics of those who graduate in engineering (‘persisters’) and those who leave engineering majors (‘non-persisters’). Matusovich et al., (2010) undertook to understand how and why students opted to enter and persist in engineering. Persistent rates of engineering students are similar to students in other disciplines; however, engineering has a gender and ethnicity gap, not seen in other disciplines. Thus, their study is all the more important to build a large and diverse community of engineers. They explain persistence with the motivation theory of Eccles, called expectancy-value theory. Eccles’ theory factors in gender and ethnic differences in STEM participation (Eccles, 2005). They hypothesized that educational, vocational and avocational choices would be most directly related to person’s expectations for success and the value they attach to the available options. The Eccles’ theory suggests that choices to engage in activities are shaped by both competence and value beliefs. Competence is about acquiring skills and applying them. Competence beliefs have been studied more widely than value beliefs among K-12 and engineering students. They are
mostly based on the self-efficacy theory (Bandura, 1977). Self-efficacy is enhanced by positive feedback, better performance, and social comparisons. Value beliefs, on the other hand, have not been that well studied. Whereas competency beliefs look at a person’s ability to engage in an activity, value beliefs consider the desire and/or importance of engaging in the activity.

The value system refers to personal importance that one attaches to the task. Matusovich et al (2010) undertook a systematic exploration of this. They asked: how do engineering students’ engineering-related value beliefs contribute to their choices to engage and persist in earning engineering degrees? The Eccles’ theory covers four value categories to describe how individuals assign importance to engaging in an activity. These value categories are: interest, importance, cost, and attainment. Matusovich et al developed operational definitions for the value categories as follows: Attainment refers to a reason for pursuing (or not) engineering that is related to the self-perceived identify of an engineer; Cost is the price of success (or failure) in terms of effort, time, and/or psychological impacts in pursuing engineering in comparison to another career; Interest is the enjoyment (or lack of) experienced in doing engineering activities; and Utility is the perceived usefulness (or lack of) of becoming an engineer and/or earning an engineering degree (Matusovich et al., 2010). The authors conducted longitudinal semi-structured interviews of 11 participants (5 boys and 6 girls) during their four years of undergraduate engineering education. They found that all four Eccles’ value categories are present; that attainment value plays a prominent role, but not an exclusive role, in participant’s choice to earn an engineering degree; and that the four categories are not mutually exclusive. In summary, the researchers found that participants can be categorized with high or low engineering-related attainment values. Participants with high attainment values have low cost values, moderate to high interest values, and moderate utility values. Participants with low attainment values tend to have moderate or high cost values, low or moderate interest values, and moderate or high utility values. The one (female) student who left the engineering program and opted for the teaching profession had low attainment value. Though the study is inconclusive on persistence (due to the small sample size), the study suggests a need to increase students’ attainment values related to engineering in order to increase persistence. That is, “we can encourage students to stay in engineering by helping them associate a perceived engineering identity with their personal identity and demonstrating the value of this association. We must help students understand what it means to be an engineer not only by teaching a variety of engineering skills, but also by exemplifying the breadth of activities engineers perform in their daily work.” Further, lower attainment values are seen among women along with greater uncertainty about engineering and engineering abilities found in them, despite their higher grades and persistence; this suggests it is very important to develop interest and competence beliefs in women to recruit and retain them in engineering fields.

A recent article in the Scientific American (Kuchment, 2013) summarizes research on attracting more girls to STEM. Female students had higher SAT scores relative to male students, in both math and verbal sections; yet they were more likely to pursue non-STEM careers after school graduation. The article makes a strong case for incorporating storytelling in STEM. Narratives, research has shown, activate the brain beyond word recognition. An Emory university study showed that similes and metaphors can activate sensory portions of the brain. A recent study in a psychological journal concluded that inclusion of more verbal skills in STEM classes might benefit and attract women students. Historically, polymaths, both men (for example Leonardo da
Vinci and Benjamin Franklin) and women (Maria Gaetana Agnesi and Hildergard of Blingen), combined multiple fields in building their perspectives. Arts and sciences were considered equally relevant. Recent engineering research also supports the notion that story telling may help engage girl students in engineering design (Lloyd 2000, Putnam 2010).

Under-represented minority (URM) students are yet another group that is not well represented in the engineering undergraduate programs. Previous research in Academic Self-Concepts (ASC) suggests that many high-achieving STEM students will benefit from the “small pond” experience at a “non-top 30” university (Marsh, et al., 2008). The corresponding theoretical premise is that perceptions of the self cannot be adequately understood if the role of frames of reference is ignored. ASC is considered to be a good predictor of future achievements. We combine here elements of informal and formal learning with near peer-to-peer mentoring, and creative problem solving, in a multidisciplinary environment, so ‘above-average’ achievers from our diverse community become aware of alternative, challenging, and/or lucrative STEM careers (Lowell et al., 2009), all while being in a “small pond” which should positively impact the ASC. We put ‘above-average’ in quotes, since there is evidence that their Social Economy Status (SES) may have artificially depressed their normative scores (Turkheimer et al., 2003).

Walther et al. (2016) have recognized the need to build in social conscience among current engineering students. They offered a mandatory 3-credit course on empathy to sophomore mechanical engineering students. They indicate that empathy comprises of three key attributes: cognitive, emotional, and responsive that together help one place themselves in place of the other person, feel the other person’s situation, and better understand social and economic disparities that may exist. They have established a long term working relationship between engineering and social science faculty members to develop contextually appropriate and intellectually robust theoretical understanding, and utilize the same to build practical educational interventions to enhance empathy in engineering students. Their college of engineering at the University of Georgia was established in 2012 with the goal to educate a contemporary engineer who has excellent technology skills and is innovative, but is also well-grounded with humanistic values. There is much we can learn from their innovative effort. Their effort is expected to lead to fundamental insights.

Our approach here is more pragmatic and is ‘applied’, given our university’s status as an older institution, with well-established scopes and responsibilities for each college. Our engineering students take social studies and humanities courses offered by other colleges as service courses. Our faculty would not be considered qualified to teach those courses. A more practical approach would leverage the current infrastructure: we will develop executable case studies with our engineering students in a junior level course. They will be part of a multi-disciplinary team with concurrent courses taught by engineering and social science professors to students in their respective disciplines. Student teams, then, will develop the executable case studies.

Case studies tell a story (CTL, 1994): “A good case presents an interest provoking issue and promotes empathy with the central characters.” They tell a story that involves issues or conflicts that need to be understood and resolved to the best extent possible, since there may be no single or clear-cut solution. Case studies can provide a rich basis for developing students’ problem solving and decision making skills (CRLT, n.d.). The curricula in business, law and medical
schools have been based for decades on the analysis of real world cases; however, this has not been the case in engineering. We believe that what-if case studies of social and societal issues have the potential to not only bring URM and women students into the engineering fold, but also to make our mainstream engineering students more involved and intellectually more curious about social issues.

We need to provide a ready-to-use platform for such explorations at the university level. It should help nudge engineering faculty members and students to become more open to collaboration with colleagues in liberal arts. This ‘platform’ at our university has been a multi-disciplinary team project that involves faculty members and students from engineering and non-engineering disciplines. This paper benefits from our experiences with multidisciplinary collaboration that has helped engineering students build critical thinking, systems approaches, and alternate solution scenarios (Donate et al., 2015, Shankar et al., 2017 a & b). These multidisciplinary teaching alliances have involved professors and students from engineering and digital arts, and a content field such as urban planning, education, nursing, or business. The end product has been smart phone apps. We have published 55 such apps at the open source Github site (For museum apps developed by high school students, see MODS15 and MODS16. For Health care apps developed by cross-disciplinary teams of engineering, arts, and nursing, see GitHub, 2016). We have also conducted significant amount of research on building such transdisciplinary collaborations, at the level of both faculty members and students. Pre and post-surveys have shown significant improvements in technical and soft (team) skills (Donate et al., 2015).

Such collaborations have yielded two relevant insights: there was overlap in skills and interests of some engineering and arts students, especially among ethnic groups underrepresented in engineering (URMs) and women (our sample size is, however, small). The digital arts students, who eventually took some computer science courses (to procure a specialization certificate), performed well enough in those courses. We also found anecdotal evidence of students who were now in digital arts, but had started out as computer science majors. One could hypothesize that incorporation of multimedia arts, visualization, animation, and narrative building might help spark interest in computer science for some of the same URM and women students who opted out. Our proposed what-if case study approach can provide a summary of a current social or societal concern or issue, the various tradeoffs achieved in different MSAs (Metropolitan Statistical Areas) in the US, and their consequent impact on the quality of life for the MSA habitants. This can be a powerful narrative to stimulate the brains of women students to explore alternatives. Animation, visualization, and social context may pique the interests of the URM students and empower them to explore further and contribute to the discussion.

**Research Literature:**

Our approach is derived from two theoretical models with strong emphasis on student involvement in the learning process: active student engagement (ASE) and project-based learning (PBL). Both approaches assume active student participation in learning practices where exchange of ideas, extensive collaboration, and interdisciplinary synergies are essential (Tinto 1998, Krajcik et al. 1999, Kuh et al. 2007). We also leverage two recommended pedagogies: scaffolding students in their metacognition process to become self-directed learners (Ambrose et
al. 2010) and creation of a teaching program focusing on case discussion pedagogy (Barnes et al. 1994). We wish to synergistically combine the two pedagogies and the two learning paradigms in our program by (1) having faculty members develop multi-disciplinary case studies (perhaps with the aid of MS theses students), (2) using these as scaffolding examples for students in multidisciplinary teams at the junior level, and (3) measuring the improvement in a student’s metacognition process when the student undertakes a capstone team project in a later semester (Bransford et al., 2000).

Theoretical Basis:

Conceptualization of active student engagement (ASE) is associated with a critical reflection on knowledge gains including theoretical premises such as motivation; building results-oriented mindset, “learning in context”; “a bias for reflective action,” and persistence and flexibility (Fullan 2006, p. 8). The concept of active student engagement sits at the heart of the theories of student success and retention. Vincent Tinto, a leading researcher in the field of student retention and success, emphasizes the importance of actively involving students in learning activities as they enhance their chances to learn and succeed (Tinto 1998, 2006). Research also reveals the underlying relationship between student achievement and a socially active learning environment that can engage students at cognitive, behavioral, emotional, and social interaction levels (Tinto 1998, Kuh et al. 2005; Tinto 2006; Kuh et al. 2007). In the context of engineering education, Downey et al. (2005) and Downey (2008) discuss the importance of engaging engineering students beyond the mathematical formulation for which their expertise is predominantly sought. Downey (2008) provides an overview of an experimental course in Engineering Cultures which seeks to explore professional growth in terms of developing new roles for engineers through active learning, self-assessment, intellectual advancement, and critical participation. Gallini and Moely (2003) also suggest that in active learning environments students develop a sense of competence beyond the course that builds confidence in applying innovative solutions to complex problems in the greater context of the society. In addition, industries and communities will benefit from a potential group of individuals trained in related technologies with awareness of team synergy and boundary-spanning problems.

Project-based learning (PBL) is a step-by-step pedagogical approach centered upon using substantive and procedural knowledge to develop solutions to complex real-world problems (Brown and Campione 1994, Krajcik et al. 1996, 1998, 1999). PBL involves using specific cognitive and behavioral tools and classroom settings to enhance student involvement in formulating research questions, engaging in investigations about priorities, alternatives, time and resource constraints, and feasibility, designing methodologies for exploring them, collecting and analyzing data, and involving students and instructors in collaboration and dialogues with community leaders (Krajcik et al. 1996, 1999). PBL enables students to construct knowledge about the domain of application and about the processes that lead to a successful project implementation in a real-world setting. Thus, each of these features provides opportunities to build upon and expand boundary-spanning learning.

In the proposed research, we employ the principles of active student engagement (ASE) and project-based learning (PBL) as reflected in the following strategies:
• Encourage interdisciplinary perspectives where engineering students (with technological knowledge) are actively engaged in collaboration with urban planning students (with substantive knowledge), and public administration students (with knowledge of governance and public policy) to solve a complex problem and create a product that addresses the problem or research question.

• Encourage active learning environments where dialogue, reflection and leadership are essential.

• Build upon and expand learning on boundary-spanning real-world problems.

The cross disciplinary pedagogy is built upon the expectation that students will apply their domain specific knowledge towards a common goal (i.e., developing a case study), and examine the applicability of these modules in the context of topics such as coastal conservation, climate change, disaster management, and sustainability. Others have proposed transdisciplinary collaborations in the learning environment to solve ill-structured problems of the real world (Wagner, 2014).

Pedagogical Basis:

We will use scaffolding of students to enhance their metacognition process to become self-directed learners and develop a teaching program based on case studies to facilitate that. These derive from two seminal works from leading university researchers: A group of learning researchers at Carnegie Mellon University, recommend seven research-based principles for smart teaching, one of them being self-directed learning (Ambrose, et al., 2010). According to them, to become self-directed learners, students must learn to assess the demands of the task, evaluate their own knowledge and skills, plan their approach, monitor their progress, and adjust their strategies as needed. Scaffolding, a recommended strategy to help metacognition (“the process of reflecting on and directing one’s own thinking”), refers to the process by which instructors provide students with cognitive supports early in their learning, and then gradually remove them as students develop greater mastery and sophistication. We propose to achieve this with the aid of well-developed and documented case studies. These will be ‘executable’ case studies; that is, the user will be able to explore what-if scenarios, an important avenue to gain insight, explore alternatives, and determine tradeoffs. For example, Figure 1 plots our case study data for top 50 Metropolitan Statistical Areas (MSAs), for Hispanic and African American populations. This is described in more detail under “Results.” The sliding bars and options on the left can be used to filter the data to select a subset of data and highlight MSAs that meet the requirements. We will use the process developed by Harvard University researchers to develop case studies and teach them (Barnes et al., 1994).
Figure 1: What-If Scenario Analysis using IBM Analytics Tools

Methods:

Professional Formation of Engineers (PFE), a NSF initiative (PFE, 2015), has the goal to understand and measure engineering thinking, doing, making, and knowing. In this project, we focus on thinking, doing, and knowing, moving the making part to a capstone design project course. To achieve this, a cross disciplinary group of students and/or faculty members will participate in building case studies of social and community relevance (the thinking part). For engineering students, this will be followed by reflection on engineering solutions to improve the case-study framework (the doing part), and making a presentation on their alternate solution(s) to a group of professional engineers (the knowing part). It is hoped that these students, when they eventually choose a capstone design project in their senior year, will build a relevant engineering solution (the making part). By monitoring these various stages with rubrics, we will be able to put the process on a firmer footing to learn from and improve.

Assessment Strategy:

Bransford et al. (2000), a National Research Council sponsored committee on developments in the science of learning, recommend conducting research on formative assessment. They recognize that metacognition skill development takes time and suggest a curricular level intervention to encourage assessments across multiple grade levels in K-12 (page 257). To test our hypotheses, we adapt their approach here to engineering undergraduates, by providing scaffolding case studies for their team project at their junior level, allowing their metacognition
skills to develop for one year, and then assessing the impact of our intervention in graduating students when they undertake an engineering design project (in their senior year).

Design of Survey Instruments: The first instrument (pre and post surveys) listed below will be used only with the group of engineering students who are enrolled in this elective junior level course (the ‘studied’ group). The second instrument (pre and post survey) will be provided to all engineering and social science students who will form teams and address a common what-if case study. The third measurement will be a comparative study and is planned to be undertaken later, for engineering students, at the time of their graduation as engineering majors (typically two years hence). The engineering students who elected not to participate in this course will be the ‘non-studied’ group. Such groups are typically called case-control groups. However, since we use the words ‘what-if case study’ in a different context, we decided to use ‘studied’ vs ‘non-studied’ to lessen confusion.

- **PFE Skills Rubric:** A PFE rubric based on thinking, doing, making, and knowing will be developed for this purpose by the engineering faculty member and a small volunteer group of retired engineers. All faculty members involved (from engineering and social sciences) will discuss and add survey questions on engineering identity. This is applicable to the ‘studied’ engineering group of students only.

- **T Skills or Content Survey:** This will be designed as a questionnaire instrument, with a mix of both closed and open-ended response types (Bernard 2011). It will be designed to measure student awareness of issues and attitudes associated with the wider societal contexts, STEM interest as a consequence of the exposure to the case studies, and potential for STEM solutions. This will be taken by both the ‘studied’ group of engineering students and the social science students who participated with them in the what-if case studies.

- **m (modified) ABET Rubric:** This will be developed together by the faculty members involved (Kline, 2005). We will improve upon the Pass/Fail ABET (3) criteria and develop a rubric with letter grades. Volunteer engineering professionals will evaluate senior engineering students at the completion of their capstone design project. Since our junior level course is an elective course, we expect a comparative study (studied vs non-studied groups of graduating seniors) out of this. One of the authors has been an ABET accreditation coordinator (Shankar et al., 2013a and 2013b).

**Hypotheses (as related to our what-if case study-based curriculum):**

- **Hypothesis 1:** Participation, identification, and development of multiple engineering and non-engineering solutions will help URM and women engineering students to enhance their engineering identity. This translates to: “The PFE skill score is significantly higher in the ‘studied’ group relative to the ‘non-studied’ group.”

- **Hypothesis 2:** Exploration of social issues will help improve sensitivity of engineering students to social issues. This translates to: “The T skills survey rank is significantly higher in the ‘studied’ group relative to the ‘non-studied’ group.”
Hypothesis 3: Scaffolding of the engineering students will lead to significantly improved soft skills at the time of graduation with an engineering degree. In our study, this translates to: 'mABET Survey rank is significantly higher in the 'studied' group relative to the 'non-studied' group at the time of graduation.' This is measured one to two years after the time such a course is offered to the 'studied' group.

Implementation Overview:

To test the hypotheses and to implement the project, we propose five modules which will embed both (1) the development of new roles for engineers in social decision-making through active learning and (2) the critical participation and corresponding assessment strategies of knowledge gains. This two-tier approach incorporates new knowledge/tasks for students, and assessment tasks for the research team. The structure of the assignments will follow t Bloom's taxonomy (Bloom 1956) where each new assignment moves to a higher level with each module. For example, Module 1 is descriptive and focuses on knowledge acquisition, Module 2 focuses on comprehension and understanding of materials to formulate questions, Module 3 moves to application, while Modules 4 and 5 will focus on analysis, evaluation, and creation. With each Module there will be a set of tasks undertaken and an assessment. The final product will be a synthesis of engineering knowledge and social, political, economic, and ethical considerations.

Module 1: Introduction. New knowledge/ tasks: The social science professors and the engineering professor will discuss the role of computer technology in community development and public policy. The students will participate in an active discussion and develop concept maps to illustrate some social, political and ethical considerations that are often part of the engineering work. The students will be given their first assignment which will be to focus on selecting a case study area. Potential topic areas might include, but are not limited to, topics such as sea-level rise, transit-oriented development, pollution reduction, increasing resilience of cities, crime patterns, renewable energy portfolios, social justice, etc. The discussion will focus on the role of computer technology in community development and public policy. Diagnostic assessment: As part of module #1, the research team will conduct a pre-test to elicit understanding/ misunderstanding of social science concepts as they pertain to the engineering work. The students will also submit their first student teams’ progress report.

Module 2: Getting started. New knowledge/ tasks: the students will apply the knowledge they have acquired in Module #1 to formulate questions that address community needs, select a topic for their engineering project and identify data sources. They will conduct literature search and finalize their topics in discussion with the social science professors. Formative assessment: students’ progress on each of the assignments can be traced by setting up a discussion board on Github where students can both ask questions and answer questions asked by their peers. This is helpful to engage students in critically assessing the knowledge they build as they complete the assignment. Keeping a log of the most commonly asked questions or creating Question & Answer blog will be a useful tool for formative assessment. The student teams will submit their second progress report.
Module 3: Data collection and Methodology-

Technical, Social-economic, political, ethical, and Community Considerations: **New Knowledge/Tasks:** To answer the research questions developed in Module 2 for their topic areas, students will first assess what kinds of data they will need for the case study topic. They will then apply knowledge from engineering and the social sciences to collect technical data which will be combined with data on socio-economic, political, and demographic variables. Secondary data sources will include census data, and data from government agency reports. The latter include agencies such as the Environmental Protection Agency (EPA) and the Bureau of Labor Statistics (BLS). Data will also be collected from the state and local level administrations. Faculty members from the social sciences will provide guidance on the various data sources for socio-economic data and the professor from Engineering will guide students on extracting, cleaning, and preparing the data for input into the What-If analytic program. **Formative Assessment:** Each student team group will post their data sources and data into a Group Journal at their Github Repository. They will also use Github for a group discussion on questions and any concerns related to data such as availability, format, time frames, appropriateness, etc. The data collected will then be uploaded into an Excel spreadsheet for use with an IBM Analytics online resource, called Bluemix. It is a free resource for academic activities.

Module 4. Conceptual Model: **New knowledge/tasks:** At this stage of the project development, the students will be asked to develop and present a conceptual model of the project. **Formative assessment will consist of internal and external evaluation. Internal evaluation:** The “windshield check” concept (Tomlinson 2010, 2014) can be particularly useful. Using this concept, students can check their understanding of the assignment with regard to what they see through the “windshield”: CLEAR (I thoroughly understand what is required of me), FOGGY (there are parts of the assignment that are still unclear), and MUDDY (I am not sure where I am going). **External evaluation:** A group of working professionals from the disciplines will be invited to the conceptual presentations and provided a rubric to evaluate the intermediate student projects across seven categories: relevant, applicable, technically advanced, targeted to a specific audience, informational, educational and with a business acumen.

Module 5. Synthesis and Evaluation: Students will present their final project in this module which will reflect a culmination of their work in the classes. Summative assessments will be undertaken via evaluations that will be both internal and external. **Internal evaluation** will include a post-test assessment to gauge students’ knowledge, understanding, and application of social science concepts as they pertain to the engineering work. The students will also submit their last team progress report. Within that report, they will include a group evaluation assessing what they learned from other team members and reflections on what helped and hindered the team’s progress, and their reflections on the inter-disciplinary nature of the team. Students will also complete a post-project survey with both structured and open-ended questions about the project. The final project will also be evaluated by the research team.

**Results:**

Our paper is a work in progress. The concurrent course offerings are only planned for spring 2018, due mainly to scheduling conflicts. No student-based results can be included for this
conference. We will, however, document a case study we have developed, to facilitate the offering of these courses. This case study was developed as part of a MS thesis in computer science (Terrell, 2015).

A specific Case-Study:

Case Study: Title: Socio-economic demographics of four racial/ethnic groups and corresponding police-initiated homicides

Case Study: Introduction:

In this study we examine socio-economic demographics of four racial/ethnic groups and corresponding police homicides occurring in 100 of the highest populated metropolitan areas in the United States for the year of 2015 (n=400). This case-study used a J48 – decision tree algorithm to compare data across different races and ethnic groups for predicting factors in police homicides.

Case-Study: Motivation:

There is a perception that, in the US, certain minority groups are victims of police homicides at a disproportionality higher rate when compared to other ethnic groups. Media coverage of recent episodes has fueled this discussion further. Such events may seem to imply that issues concerning racial inequalities in America are getting worse. However, we did not know whether such indications were factual, whether it was a recent phenomenon, whether racial inequality was escalating relative to earlier decades, or whether it was better in certain regions of the nation compared to others. The Null Hypothesis in our study states that there is no significant difference related to the societal issues affecting the life chances of various ethnic groups, in this frame of reference.

Case Study: Dataset Generation:

We initially described our requirements and integrated endpoints from various data sources including census.gov, fbi.gov, the Guardian’s “The Counted”, and multiple city websites. We first collected racial/ethnic demographic information on 100 of the highest populated Metropolitan Statistical Areas (MSAs) in the United States ranging from New York-Newark-Jersey City, NY-NJ-PA Metro Area with a population of 20,095,119 to Durham-Chapel Hill NC Metro Area with a population of 543,217 according to the Annual Estimates of the Resident Population provided by the Census Bureau’s American Fact Finder (Beureu, 2014). Table 1 below indicates the range of possible demographic factors collected for each race.

Table 1 Demographic Factors

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Poverty Rate</td>
<td>The percentage of a population who are in poverty</td>
</tr>
<tr>
<td>Education Attainment</td>
<td>The highest level of education that an individual has completed. This measurement includes ‘No High School Degree’, ‘Some College’,</td>
</tr>
</tbody>
</table>
and ‘Bachelor’s Degree or Higher’.

<table>
<thead>
<tr>
<th>Per Capita Income</th>
<th>Average income for each race and ethnicity</th>
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<tbody>
<tr>
<td>Population</td>
<td>The population count or estimate for each race</td>
</tr>
<tr>
<td>Median Income</td>
<td>The amount which divides the income distribution into two equal groups, one half having incomes above that amount, and the other half having incomes below that amount</td>
</tr>
<tr>
<td>Race</td>
<td>Asian, Black, Hispanic, and White</td>
</tr>
</tbody>
</table>

MSA crime rates were collected from the Federal Bureau of Investigation (FBI, 2016). Homicide rates collected by the FBI may be incomplete. Law enforcement agencies may or may not choose to submit their annual count of “justifiable homicides.” For this reason, we obtained homicide rates for each race within each MSA from a dataset provided by Guardian (2015). The dataset seems to have comprehensively tracked the number of police homicides.

Our database was created in the Attribute Relation File Format (ARFF). ARFF supports a variety of data types for attributes such as real, numeric, nominal, etc. Once attributes and their data type are defined, records can easily be added. Figure 2 shows the block diagram of the case study flow. Our dataset has 400 records, with 4 records per MSA, for each of four major ethnic groups. After building the dataset, the J48-decision tree algorithm was used to classify the demographic/police homicide data. Results of the algorithm are measured in terms of correctly classified instances, confusion matrix (a compilation of true/false positives and true/negative negatives), and several measures based on this matrix (such as Precision, Recall, the F Measure and MCC). Classification results may be used to determine a particular person’s risk of police homicide (Boolean: below or above average), given the person’s education attainment, income, and race.

![Figure 2: Block Diagram of case-study development](image-url)
Case Study: Classification using the J48-Decision Tree:

J48 is a data mining algorithm within WEKA (WEKA, n.d.). It has been used to generate a decision tree subsequent to classification by the C4.5 algorithm for an overlapping application (Sakhare, 2014). It uses a ‘divide and conquer’ approach to grow a decision tree. Classification techniques require large training and testing datasets to reduce the effect of missing values. The dataset of 400 records was divided into a training dataset and a testing dataset (280 and 120, respectively). The training dataset was used to build the classification model, while the testing dataset was used to validate the model. The J48-decision tree may then be used to classify a given person into either of the two classes (below or above average risk).

Case-Study: Results

Table 2 displays our confusion matrix which contains information about actual and predicted classification done by the classification model (Key: Low Risk – Below Average Police Homicide Rate; High Risk – Above Average Police Homicide Rate)

<table>
<thead>
<tr>
<th>Test dataset: n = 120</th>
<th>Predicted: Low Risk</th>
<th>Predicted: High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual: Low Risk</td>
<td>73</td>
<td>8</td>
</tr>
<tr>
<td>Actual: High Risk</td>
<td>14</td>
<td>25</td>
</tr>
</tbody>
</table>

Case-Study: Conclusion

After building and training our J48-Decision Tree model it was determined that education attainment, race/ethnicity, per capita income and median income were the four top factors in predicting above average police homicide rates for a person. Whether or not a person attended “some college” appeared to be the most important attribute in the decision tree process. MSA crime rates and poverty levels did not play a major role in predicting the police homicide rate.

Case-Study: Future Scope

Future extensions could focus on revenues received by MSAs through their police departments, effectiveness of sensitivity training, and prior records of police officers. Improving education opportunities for minority youth may be a pro-active solution. Since there are 100 MSAs, it is possible to determine which of the MSAs have solutions that are working and emulate them elsewhere where a change is warranted. From an engineering perspective, some of the solutions that can be considered are: better body camera data streaming; integration of audio signal processing; mobile app development useful to police officers and minority youth, community blogs for interaction between the two groups, and enhanced transparency among all the subgroups involved.
**Discussion:**

The current status: We have completed one case-study and expect to develop two more case-studies by the end of this year. We will offer concurrent courses in spring ’18 and add the top 3 to 4 case-studies from the course to our case-study portfolio. We will also monitor our students as per the hypotheses questions listed earlier.

Engineering Implications: Beyond educating engineers on social issues and providing new insights based on data analytics, such case studies can provide an avenue for engineers to apply their problem solving (the doing, making and knowing of the PFE vocabulary) skills.

In the longer run, our case-studies can be introduced as exercises or research problems in some sophomore courses in humanities and social sciences. This will hopefully help recruit more URM and female students to engineering. Going even further, such case studies can be introduced at the high school level to influence the decision making even earlier. Students will also get exposed to Python, a popular and easy-to-learn programming language (Our case study methodology uses Python).

**Conclusion:**

This paper focuses on attracting URM and women to engineering, and creating greater opportunities and preparation for current engineering students to engage in interdisciplinary endeavors, especially in relation to complex sociotechnical systems. This project will expose engineering students to such a multidisciplinary project in their junior year. It is hypothesized that URM and women students’ engineering identity will be strengthened after taking such a course. It is further postulated that all engineering students will benefit with improved technical and soft skills, and a better appreciation of social issues and their role in evaluating, quantifying and (at least partially) resolving them. Such engineering students will be formatively evaluated in their senior year after they complete their engineering design project. It is hypothesized that engineering students who take this course will exhibit better professional skills and community awareness at the time of their graduation.

Academia is ideal for multidisciplinary collaborations. This team project framework judiciously combines teaching, research, and community service to give faculty members reasons to collaborate. A group of collaborators may address their own community issue. A well-integrated case study can provide quick and reliable answers to lay people who lack time and knowledge to probe further, thus democratizing information. Such projects will give an opportunity for engineering students to truly understand and appreciate the roles of humanities and the social science disciplines. A typical engineering school is unique in its student population, with under-representation of women and certain minority groups. Student populations in humanities and social sciences are better balanced. It is hoped that eventual introduction of these case studies in sophomore courses will help engineering become more acceptable to women and URM students.
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