Developing a First-Year Engineering Course at a University in India: International Engineering Education Collaboration

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Developing a First-Year Engineering Course at a University in India: International Engineering Education Collaboration

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Abstract: This paper presents the results of collaborative efforts between Virginia Tech and KLE Technological University in Hubli, India to develop a first-year engineering program at KLE Technological University. A one-week workshop was held in June 2015 by one faculty and two PhD students from Virginia Tech for 25 faculty at KLE Technological University to (1) provide support in the form of shared experiences and knowledge for developing a university-wide first-year engineering course, (2) assist in the development of a Center for Engineering Education Research, and (3) initiate a real-time watershed monitoring station in India based upon a station at Virginia Tech for supporting the first-year course and collaborative watershed and engineering education research. Assessment of the one-week workshop included multiple surveys using qualitative and quantitative questions. Results indicate that faculty found the workshop useful and were motivated to improve their own teaching and pursue engineering education research. The first-year course was implemented for the first time in the fall 2015 semester with an enrollment of approximately 500 engineering students. Student learning and motivation in the course were assessed using qualitative and quantitative survey questions. Course implementation and assessment are ongoing at the time of this submittal but results will be included in the final presentation.

1. Introduction

Poor retention rates within engineering are often due to a lack of competence of students as they reach sophomore classes, poor instruction, a lack of a sense of belonging, or a lack of interest in engineering courses[1,2]. Due to a need to improve retention, many engineering educators are focusing their attention on improving early engineering curriculum as it is generally known that the first two years in an engineering program are crucial to student retention and success. As a result, many institutions are making efforts to enhance the first-year engineering experience through first-year courses that adequately prepare students for their later courses in engineering while at the same time providing engaging hands-on problem solving experiences.

Successful first-year engineering courses will often incorporate contemporary learning theories and pedagogical practices into the classroom. On example is active learning, which is a theory that proposes that student learn more by doing meaningful activities and is often implemented by injecting student activities during lecture time[3]. Research has shown that active learning techniques, such as hands-on activities or think-pair-share, are more effective than traditional lecture based classes[4]. Another learning theory commonly used is collaborative learning, which proposes that students learn better when they are working together to achieve a common goal[5]. These contemporary pedagogical practices can also be used to improve not only the first-year experience but the overall four year experience of the student. A specific example of this is spiral curriculum, which is defined as a curriculum in which students see the same topics throughout their schooling (i.e., from first-year to senior year), where each encounter of the topic reinforces previous learning and increases in complexity[6].

In recognition of the importance that first-year courses can have on an engineering program, KLE Technological University made the commitment to develop the first college-wide first-year engineering course at the university required of all engineering freshman. As part of the development of this course, a one-week workshop was held in June 2015 by one faculty and 2 PhD students from Virginia Tech for 25 faculty at KLE Technological University. The overall goals of the workshop were to (1) share experiences of developing and implementing active and collaborative learning activities into a first-year engineering course at Virginia Tech, (2) provide assistance in developing active and collaborative learning activities for the first-year courses at KLE Technological University, (3) initiate a project to develop a counterpart of the Virginia Tech real-time watershed monitoring lab at the KLE Technological University to support the first-year program, and (4) leverage experiences from the first-year engineering program into other courses at KLE Technological University through a spiral curriculum approach.

The following paper describes the workshop methods, assessment of the workshop, and results of the assessment. The first-year engineering course was implemented in the fall 2015 semester, and a brief description of the course and the assessment strategy are discussed. Collaborative engineering education research efforts and assessment of the fall 2015 data are ongoing and results will be included in the final presentation.

2. Workshop Summary

2.1 Experiences from First-Year Courses Topics

One of the goals of the workshop was to share experiences from college-wide first year engineering courses at Virginia Tech. First-year engineering courses are required of all engineering freshman (~1,500 / year) at Virginia Tech with the purpose of introducing engineering students to the profession, data collection and analysis, mathematical modeling, problem-solving, software tools, design, professional practices, communication, teamwork, ethics and the diversity of fields and majors within engineering. A major focus of this component of the workshop was to introduce the faculty to active and collaborative learning problem solving activities that could be incorporated into a first-year course.

There were a number of first-year engineering topics and activities covered in the workshop including the following:

- **Straw Towers**. In this design/build activity students are given soda straws to build the tallest structure that makes the most efficient use of a constrained amount of materials (Figure 1). This activity enforces design, teamwork, and problem-solving among the students.
- **Balloon Drop**. In this activity students are provided with a fictional scenario in which they must build a landing pad out of a set of materials that will absorb the impact from a water balloon dropped from a given height without the water balloon breaking (Figure 1). Like the straw towers activity, this activity enforces design, teamwork, and problem solving among the students.
- **Sustainable Energy Design Project (SEDP) Background & Implementation**. For this project, students are required to design a promotional innovation to publicize awareness of a renewable

energy source (e.g., solar, wind, hydro, geothermal, biomass, etc.). The selection of the task is up the student group, but the product, system, or process the students create is required to be functional, safe, useful, and engaging. This activity requires students to (1) apply the principles of sustainability to the design of a product, system, or process, (2) apply the design process to solve and engineering problem as part of a team, and (3) effectively describe their teams product by conveying their challenges, solutions and reasoning both orally and in writing.

- **Mechatronics**. In this activity students are required to build a two-wheel mobile robot. Student groups work in teams of three to build a motor driver circuit, assemble the gearbox, and attach a power source to complete the robot (Figure 1). In this workshop students learn introductory concepts of electronic components, breadboard operation, and robotics. Students also learn teamwork, communication, problem-solving, and design concepts.
- **Ethics**. This activity provides an overview of ethics education within engineering including pedagogical trends such as the case method and ethical frameworks (i.e., code of ethics, moral theories). It includes watching an engineering ethics video followed by questions and discussion that explore ethical responses to a wide range of situations an engineer may find themselves in.
- **Watershed Monitoring Project**. This project requires students to use a set of stream flow, water quality, and weather data to develop a decision support system in the form of a modular MATLAB program. The students are assigned a water quantity analysis and water quality analysis with regards to road salts and biological indicator species. During this project students develop a working knowledge of contemporary software technologies, programming, problem-solving, and teamwork.

In addition to these activities, instructors were introduced to methods of technology enhanced learning and flipped classrooms. Technology enhanced learning included sharing experiences with Tablet PC's required of all students at Virginia Tech as well as an introduction to types of classroom instruction and assessment software. Non-traditional methods of conducting a class such as flipped classroom theories and examples were also introduced to the instructors as a possible instructional methods.

Figure 1. Instructors participating in the soda straw (top-left), mechatronics (top-right), balloon drop activity (bottom-left and bottom-right).

2.2 Developing the First-Year Course and Integrating Spiral Curriculum

After an introduction to experiences in first-year course activities and projects, the focus was turned to developing an implementation plan for the first offering of the first-year course at KLE Technological University in the fall 2015 semester. This included mapping activities from the workshop to course objectives and desired outcomes of the course as well as developing a week-by-week organization of course materials. Adopted components from the workshop included soda straw towers, balloon drops, mechatronics, ethics, and watershed monitoring.

Efforts were also made to leverage first-year activities from the workshop throughout the four year engineering experience through a spiral curriculum approach. Spiral curriculum was introduced as a way to weave concepts throughout an engineering program in multiple courses from the first-year to the senior year. The following basic elements of spiral curriculum were introduced: authentic engagement from the beginning, thematic curricular organization, periodic revisiting of key topics and themes, increasing complexity with support, and student mastery of the learning process. As an activity, examples of spiral curriculum were introduced and instructors were required to think and demonstrate how spiral curriculum could be used within their own courses. Figure 2 demonstrates an example of how one group envisioned spiral curriculum being used under the theme of ethics and data acquisition.

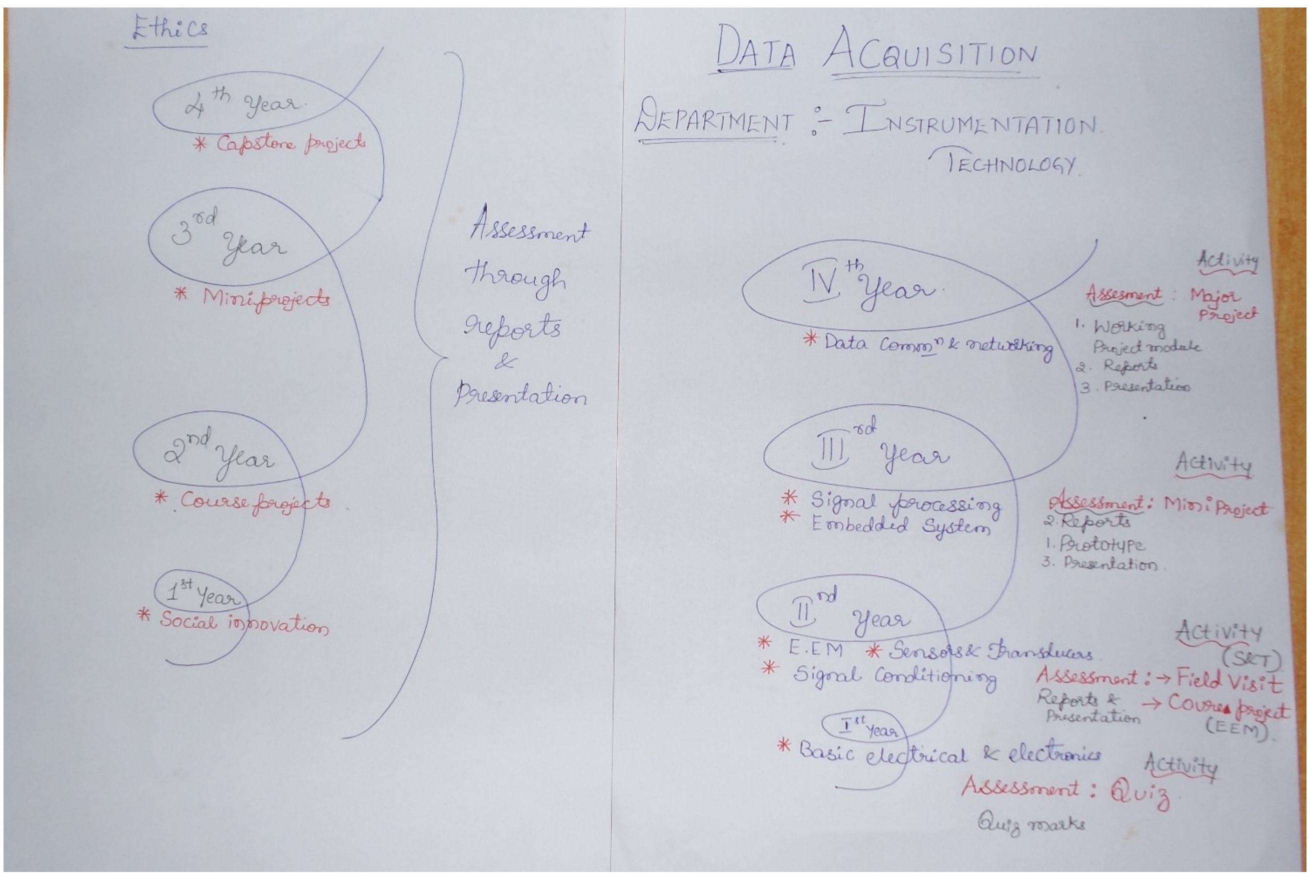

Figure 2. Spiral Design Example from Faculty Workshop

2.3 Developing a Real-Time Watershed Monitoring System

Another goal of the workshop was to initiate a watershed monitoring system, such as the one at Virginia Tech, at KLE Technological University. The watershed monitoring station at Virginia Tech, known as the Learning Enhanced Watershed Assessment System (LEWAS), is comprised of flow, water quality, and weather instrumentation that collects data in high-frequencies (1-3 minutes) and broadcasts the data in real-time through an open-ended online watershed learning environment[7]. This data has in turn been used in over 16 courses at multiple institutions, including first-year courses at Virginia Tech[8]. A LEWAS-type watershed monitoring system at KLE Technological University would enable instructors to incorporate real-time local data into their first-year course and others through activities such as the Watershed Monitoring Project discussed in section 2.1.

A real-time watershed monitoring system such as the LEWAS has the ability to replace traditional teaching methods with student-centered experiences that incorporate non-stationary data in an active learning experience. This is important, as two of the greatest challenges facing hydrology education in the 21st century include providing student-centered activities and field experiences in the classroom[9], and replacing historical stationary data with real-time, dynamic, and temporally and spatially variable hydrologic systems[10]. In the context of international engineering education, a focus on water education is important as a recent United Nations report projects that water demand will increase globally by 55% by the year 2050, and with this increase in demand the world is expected to have a global water deficit of 40% by 2030[11]. Educational experiences that can give an international perspective to water, such as access to real-time watershed monitoring stations in the U.S. and India, would provide excellent global experiences for students. Therefore, another goal of this effort is to create an integrated system where students can access watershed data from the U.S. and India in support for multiple classes across all levels of higher education (first-year through graduate school) and across multiple institutions and countries.

This portion of the workshop included sharing materials on the development of the watershed monitoring system, instrumentation used, computing resources, power considerations, and online data sharing. The ways in which the watershed monitoring system is integrated into multiple courses from freshman to graduate courses across multiple institutions was also shared. Finally, an implementation plan for developing a watershed monitoring station at the university in India was developed. This implementation plan included two phases. The first phase to be implemented over the course of one year includes site identification, flow sensor installation, water quality grab sample collection, and data collection and maintenance procedure development. The second phase to shortly follow includes developing real-time communication with the sensors and installing in-situ water quality sensors. Near the conclusion of the workshop, a tour of 5 potential site locations for a watershed monitoring station was conducted, and a site was decided upon. Figure 3 shows the workshop participants visiting a potential site for a watershed monitoring station located near a bridge stream crossing.

Figure 3. Workshop participants visiting a potential watershed monitoring station location

The outcome of this effort will be a real-time watershed monitoring station that can be used to support engineering education initiatives in the first-year curriculum. In addition to the Watershed Monitoring Project discussed in section 2.1, other active and collaborative learning activities that leverage a local real-time watershed monitoring station were proposed. For example, one activity requires groups of students to visit the field site and collect grab samples of water quality data. This data is then used to compute a daily pollutant load for the stream and the results are compared with pollutant loads computed using the continuously collected data from the watershed monitoring system. A second activity requires students to develop their own simple monitoring system by connecting a temperature sensor to a Raspberry Pi computer that collects data using Python programming. This allows students to learn about the watershed concepts as well as the electrical and computer engineering concepts needed to run this system. However, because the system at KLE Technical University is currently in development, these activities were not included in the fall 2015 course.

2.4 Online Watershed Learning System

As discussed previously, one goal of developing the real-time watershed monitoring station at the KLE Technological University campus is to integrate the data into an existing open-ended learning environment known as the Online Watershed Learning System (OWLS). The OWLS serves as a remote/virtual lab where students can see real-time watershed data from the U.S. University with anywhere anytime access through HTML5 that can be used regardless of the hardware (i.e., desktop, laptop, tablet, smartphone, etc.) or software being used (i.e., Windows, iOS, Android, etc.)[12,13]. Virtual labs are software that mimic the real environment whereas remote labs are labs where experiments are conducted remotely across the internet [14,15] and they have been shown to be effective in improving student understanding of important engineering concepts [16–18]. The OWLS has been integrated as a virtual/remote lab into a number of courses at Virginia Tech as well as Virginia Western Community College[8,19]. During the workshop the OWLS was demonstrated and a module was developed to integrate the OWLS into the first-year course during the fall 2015 semester.

2.5 Engineering Education Support and Feedback

An anticipated outcome of the workshop is the strengthening of collaborative relationships between Virginia Tech and KLE Technological University. This collaborative relationships is manifested through the sharing of experiences, resources, and assessments to improve the quality of education and develop engineering education outcomes and results. This relationship is illustrated by Figure 4, which shows the feedback loop between Virginia Tech and KLE Technological University. This loop starts with planning assessment, implementing the course and assessment procedure, analyzing and interpreting the data, and applying the data to improve future course modules and assessment. This feedback loop improves instructional quality at both universities through shared experiences and data, and strengthens engineering education research efforts.

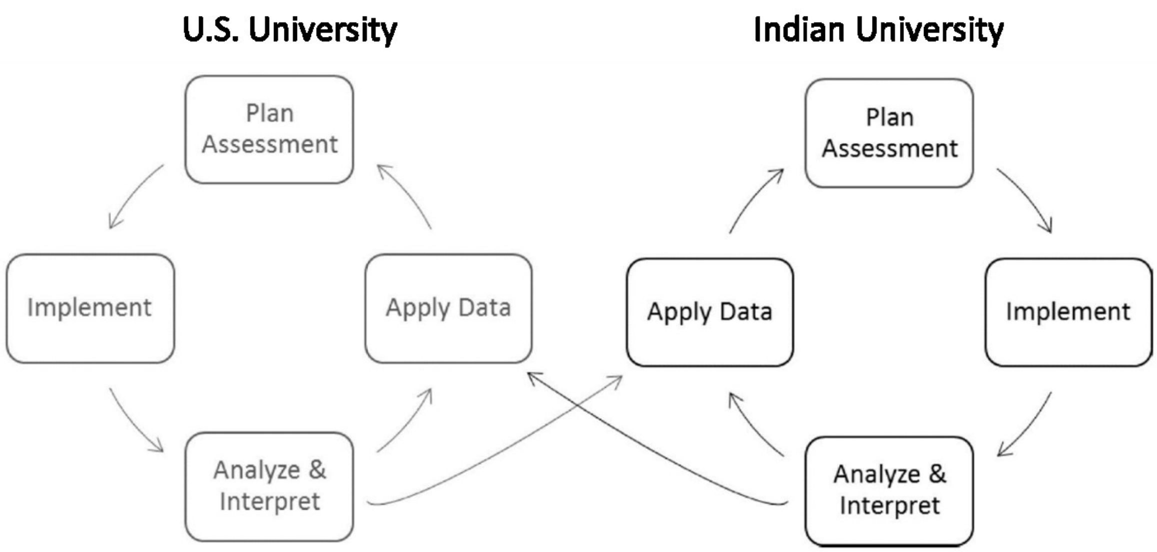

Figure 4. Feedback loop between Virginia Tech (U.S. University) and KLE Technological University (Indian University)

3. Assessment Methods

Throughout the workshop assessments were given to (1) elicit daily workshop participant feedback to improve workshop materials, (2) assess the effectiveness of workshop modules and (3) explore faculty readiness and wiliness to implement the first-year courses and pursue engineering education collaborative efforts. Assessments included daily one-minute papers that were given at the end of the day to collect workshop participant feedback on their impression of that day's activities and expectations and desires for future days. In addition, a survey at the end of the workshop sought to explore workshop participant impressions of the workshop modules, how they might be used to improve their own instruction, what ways they may develop engineering education research, and how collaborative efforts might continue. The following results summarize the assessment from the workshop and initial implementation of the first-year course at the Indian university.

4. Results

4.1 One –minute papers

The purpose of the one-minute papers was to collect workshop participant feedback on their impression of that day's activities and expectations and desires for future days. This allowed participants to provide anonymous and candid feedback on the workshop and what they would like to see in future workshop days. For example, in the first day participants mentioned "*I felt todays sessions were lengthy*" and "*Please engage hands-on sessions in the noon*", which prompted a reorganization of future sessions to more adequately space lecture and activity time. There were also many comments suggesting the sharing of reading material that the workshop facilitators then made readily available to all participants.

4.2 End of Workshop Survey

A survey was given at the end of the workshop to assess the participant perceived effectiveness of the workshop. Results indicated that participants felt that the sharing of experiences was one of the most beneficial aspects of the workshop. For example, when asked "What was the best part of the course?", one participant responded, "*Sharing of experience. Honest presentation sharing both successes and failures",* and another "*Multidisciplinary people working together and sharing knowledge*." Others valued the hands-on aspects of the workshop with one participant stating that the best part of the course was "*Hands on experiment which helps us to explain to the students based on our experiences we had during the course*." Additionally, when asked "Do you think this workshop will be helpful for your classes that you teach?" 96% of the survey respondents indicated that it would, with one respondent indicating that it would not have an immediate impact, but may be helpful over time as they reorient their curriculum.

Other questions sought to determine whether the participants would be interested in pursuing engineering education research after their exposure to the workshop. For example, when asked "Will you be undertaking any engineering education research project?", 65% of respondents indicated that they were planning to pursue engineering education research in the future with one respondent commenting "*Yes. Would like to explore areas like learning theories and applications, continuous assessment, enhancing spatial thinking capabilities and design thinking.*" Another respondent even indicated that after this workshop he or she intended to pursue a PhD in Engineering Education.

The participants were also asked questions directly related to the watershed monitoring system and the OWLS. When asked "Would a watershed monitoring lab be useful for you as an instructor?", 86% indicated that a watershed monitoring system would indeed be useful for them in their instruction. Participants were also asked to rank the learning value of different components of the OWLS. Participants indicated that the real-time data had the greatest learning value, followed by anywhere/anytime access and the interactive graph (Figure 5). This ranking was consistent with other studies where students in courses in which the OWLS has been integrated ranked real-time data and anywhere anytime access as the components of the OWLS with the greatest learning value[12].

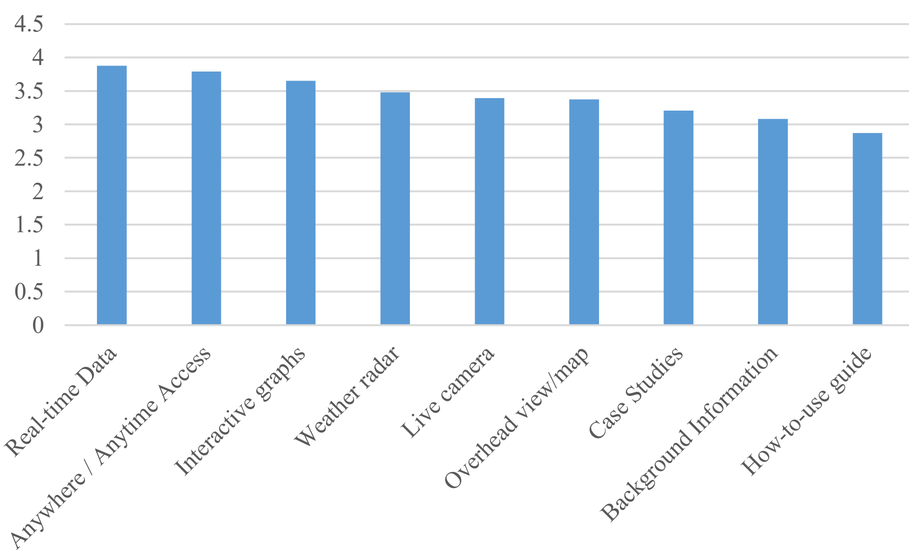

Figure 5. Survey responses to the question: What was the learning Value of the following components of the OWLS (Not valuable = 1; Somewhat valuable = 2; Valuable = 3; Extremely valuable = 4)

4.3 First-year course

The first year course was implemented in the Fall 2015 semester at the KLE Technological University, shortly after the workshop. Student activities in the first year course reflected many of the workshop activities including soda straw towers, balloon drop, mechatronics (Figure 6), ethics, and the watershed monitoring OWLS activity, among others. Additionally, the course faculty expanded and adapted the activities to fit their specific curriculum and the available resources. Assessment of the students included a mixed-methods qualitative and quantitative semester survey given at the end of the semester. Ongoing work is seeking to assess the data and results from this will be included in the final presentation.

Figure 6. Fall 2015 first-year students participating in Mechatronics activity

5. Conclusions

This paper has demonstrated how a collaborative effort between Virginia Tech and KLE Technological University in the form of a 1-week workshop has resulted in the development of a first-year engineering course at KLE Technological University. This paper has also demonstrated how such an effort can result in collaborative engineering and engineering education research through the development of complementary watershed monitoring stations and feedback loops between institutions. Ongoing collaborative work includes the implementation and assessment of the first-year course at KLE Technological University, additional visits of U.S. faculty and students to strengthen collaboration, joint presentations and publications, and proposals with faculty at each university to funding sources in the U.S. and India for continuing collaborative engineering education research activities.

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