Development and Implementation of a First-year Engineering Experience

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***Abstract* – This paper outlines the recently reimagined first-year experience at the Department of Engineering at James Madison University (Madison Engineering) that occurred during the academic year of 2014-2015. Specifically, it will discuss the framework of the courses (ENGR 101: Engineering Opportunities & ENGR 112: Engineering Decisions) and activities (Engineering Residential Learning Community) during the first-year experience. The motivation of the reimagined first-year experience was to help retain students through a learner-centered pedagogy while providing them with authentic, experiential, project based learning experiences. The courses and activities were focused in the following areas: community building, human-centered design process, engineering and society, sustainable development, engineering fundamentals, systems approach in engineering problem solving, ethics, professionalism, and communication skills. These experiences were designed to help facilitate first-year students in making their transition from high school to college and equip them for success as students within the department and beyond.**

Index Terms – Experiential learning, Project-based learning, & Residential learning community.

BACKGROUND

The undergraduate engineering program at James Madison University (JMU) is ABET accredited through the Engineering Accreditation Commission. The program was designed to develop engineering versatilists aligned with the description provided from the Engineer of 2020 by the National Academy of Engineering: one who possesses strong analytical skills, strong communication skills, a strong sense of professionalism, creativity, and versatility [1,2]. The curriculum combines a liberal arts general education core with courses in math, science, engineering design, engineering science, engineering management, systems analysis, and sustainability to instruct, train and guide the engineering versatilist [3,4].

ENGR 101: Engineering First-year Student Seminar was a survey course that was the point of access and introduction to the engineering curriculum. The one credit hour course was offered in the fall semester where the whole first year cohort met once a week for fifty minutes. ENGR 112: Introduction to Engineering was a three credit hour course that was constructed to provide an over-arching perspective of the culture in engineering and in the curriculum. The course met twice a week for 100 minutes and was offered in the spring semester by sections of twenty-five students.

Multiple iterations of ENGR 101 and ENGR 112 were offered between 2008 and 2014. ENGR 101 was last offered in the fall of the academic year of 2011-2012 and ENGR 112 was most recently offered in the fall and spring in the academic years of 2012-2013 and 2013-2014 [5].

MOTIVATION FOR REIMAGINED FIRST-YEAR EXPERIENCE

In response to the vision presented in the Engineer of 2020 Project, many engineering educators are redesigning courses and curricula to provide students with opportunities to conceive, design, and implement engineering solutions to complex global issues. The motivation for reimagining the first-year experience stemmed from a call that was put forth several decades ago (i.e., the mid-1980's) to postsecondary education to focus on the first-year experience of college students [6]. The transition from high school to college is a pivotal point in the lives of most students [7]. Some of the transitional issues to college are compounded when students are entering into engineering programs where first-year attrition from engineering is common. Too often, we expect our students to come into our engineering programs with base knowledge in mathematics and the sciences. Most engineering departments are willing to set up programs that aid first-year students in the traditional science, technology, engineering and mathematics domains through options in remediation. Yet, engineering departments typically do not allot time and support to facilitate students through the transition to college and to the engineering discipline outside of the above traditional norms. Departments often do not provide support for the development of communication skills, teamwork and team membership, time management skills, and a community identity.

Gleaning insights from Fortune 500 companies and the United States military, who in their respective domains invest significant time and resources in the training of new hires and recruits [6], the Madison Engineering first-year experience was reexamined during the 2013-2014 academic year. The outcomes of the process were to provide

curricular and co-curricular opportunities that engaged engineering students to aid in the transition from high school to James Madison University and also Madison Engineering. The course sequence should be an informative and rewarding experience for both students and faculty.

These opportunities would focus on promoting community building skills (enhancing connections between students, the Madison Engineering Department, the university, the community and the discipline of engineering) and enhancing self-efficacy in the following areas: engineering and society, sustainable development, engineering fundamentals, systems approach in engineering problem solving and professionalism.

The courses were constructed using learner-centered, experiential and project based learning approaches. The courses were also created to be a model of what is at the core of the Madison Engineering Program, which is the development of a community of learners that engenders respect, fosters excellence, promotes collaboration, inspires generosity, and encourages life-long learning.

The reimagined first-year experience included ENGR 101: Engineering Opportunities (offered only in the fall semester), ENGR 112: Engineering Decisions (offered only in the spring) and the Madison Engineering Residential Learning Community - MadE RLC (an entire year experience with associated courses in the fall and spring with the ENGR 280 designation representing independent study projects in engineering).

MADISON ENGINEERING FIRST-YEAR EXPERIENCE OVERVIEW

This paper represents the Madison Engineering first-year experience within the academic year of 2014-2015. The focus of the paper will be on the framework of the courses.

ENGR 101: Engineering Opportunities

Engineering Opportunities offered in the fall semester is designed to introduce the students to the Madison Engineering Community and career options by describing how elements of the curriculum, personal responsibility, and available electives relate to the goals and objectives of the program. The activities in the course are aimed at assisting students in successfully making the transition from high school to college, and focus on finding and defining opportunities that can produce sustainable engineering solutions for the betterment of society.

ENGR 101 had an enrollment of approximately 120 first-year engineering students. To facilitate the creation of community, the 120 first-year students were divided into "families" of approximately ten to thirteen first-year students per family that were led, by a pair of peer-mentors (students in the Madison Engineering Leadership Program). The class structure modeled a combination of a seminar, colloquium, and tutorial structures. The class met two times per week where students prepared and presented their original work for discussion and critique like that of a seminar type course. The instructors often assigned readings for each session that the students later discussed in small groups led by peer-mentors similar to the style of a colloquium. Students also worked in teams on topics and meet with their peer-mentors weekly for discussion and guidance as they would in a tutorial oriented class.

The first session of the week was a ninety-minute instructional session held where all of the first-year students, two instructors and twenty-one peer-mentors met. The students met with their first-year families for the second session of the week that was a ninety-minute application session led by two peer-mentors.

Content themes for ENGR 101 stemmed from Human-Centered Design and design thinking, systems thinking, and professionalism and ethics. Project based learning activities with assessment were incorporated into the family design challenges. The family design challenges centered on place-based challenges throughout the course that consisted of the 1st day design challenge of everyday objects, local design challenge and an international design competition using an online platform. Assessment of these activities consisted of team and individual presentations, reading quizzes, learning management system discussions, and small group discussions.

Students were instructed to share and document their process, sources of inspiration, and prototypes through sending tweets to the class Twitter account. The use of Twitter helped to:

- Create community within and across the department
- Encourage students to think about their professional online persona
- Monitor the activity of the class in real time when teams are working in different locations

The Course Outcomes of ENGR 101 are as follows:

- Identify the 5 core values and discuss the mission of the Madison Engineering Department based on how it relates to their life given time to reflect on the mission and values of Madison Engineering. *(ABET f)*
- Exercise the process of avoiding harm & seeking to do good by evaluating the ethical dimensions of an issue by addressing the 8 key ethical questions given a contemporary issue. *(ABET e)*
- Research, define, frame and develop a persuasive argument about a problem given a contemporary issue. *(ABET j)*
- Discuss attitudes and positions objectively within written and focus group forums among peers, peer mentors, faculty & staff given time to reflect on recent events. *(ABET g)*
- Demonstrate a positive association with the Madison Engineering program given opportunities to meet faculty & staff as well was working with peers and peer mentors.

ENGR 112: Engineering Decisions

ENGR 112 is an introductory course into the Madison Engineering curriculum that is meant to prepare students with the knowledge, skills, and attitudes required to make informed engineering decisions while learning about the engineering profession and the requirements for successful progression through the Madison Engineering program.

The first-year students were split into six sections of ENGR 112 that was taught by one instructor per section. Five instructors comprised the teaching cohort for ENGR 112. A lecture format with application sessions was the predominate structure for each section. Classes met twice a week for 100 minutes per meeting. Each section had a semester-long course project, which was established to be an integrating factor of the content presented in the course.

Engineering Decisions was designed to focus on the following process and content themes: learner development (self-directed learning where students are given opportunities take the initiative in increasing their knowledge, skills or performance with limited assistance); logic to problem solving (examining and utilizing processes/strategies in a methodical approach to understand and analyze engineering problems, that include and are not limited to ill-defined problems, over specified problems, and/or problems with multiple solutions); prototypes (gathering and analyzing data to mathematically model (analytical) and/or to produce tangible estimates (physical) of approximate behavior of a product, process or system along one or more dimensions of interest given information about the product, process or system). The course outcomes are as follows:

Upon successful completion of this course, the first year student will be able to:

- Learn independently using a variety of commonly available resources *(ABET i)*
- Apply a methodical approach to understand and analyze problems *(ABET e)*
- Apply fundamental physical principles, mathematical relationships, dimensional analysis, and calculations to enhance engineering decision-making skills *(ABET a)*
- Accurately and appropriately use analytical and physical prototyping to evaluate trade-offs and make informed engineering decisions *(ABET c)*
- Use common engineering tools and software to solve engineering problems. *(ABET k)*
- Communicate and justify decisions to a broad audience in a professional manner *(ABET g)*

Class sessions and student work focused on knowledge-building and/or skill-building each week and featured a range of problem types from simple and well-structured "book problems" to more complex and less defined problems with extraneous information or multiple assumptions. Through different types of problems, students learned and applied engineering fundamentals of statics, dynamics, circuits, thermodynamics/heat transfer, and economics along with other threads prevalent in the Madison Engineering curriculum like systems thinking and sustainability. Students were presented with additional skill-building topics that required out of class time and self-paced completion of the work. The skill-building or tools-based topics included the following: proficiency with MATLAB, Excel, and Solidworks. Students were encouraged to learn the basic skills (i.e., navigating the interface, using proper syntax, recreating a simple part, etc.) independently through guided tutorials, YouTube clips and lynda.com modules. The out-of-class learning was complemented with in-class workshops during which students learned about and practiced more complex tasks like lifecycle assessment of materials or flow simulation in SolidWorks.

In addition to the analytical topics described above, students also had the opportunity to complete hand and power tools training and learn about the capabilities of the engineering 3-D print lab so that they could build physical models.

Course Projects

Across the six sections of ENGR 112, students worked on three distinct projects, which required both individual and teamwork. Each project reinforced and integrated the three themes described earlier (learner development, problem-solving, prototyping/modeling) and emphasized using engineering analysis and tools to make decisions. However, as indicated by the project descriptions, each project required students to develop specialized knowledge, which differed across the project contexts.

- Explore More Discovery Museum – Students were challenged by the Explore More Discovery Museum of Harrisonburg, VA to design and prototype an interactive display for 8-12 year olds to demonstrate the limitless possibilities from learning programming and basic electronics. The museum wanted to use such displays for engagement and enrichment activities and programs related to programming and electronics. By learning the Arduino microcontroller architecture and programming language, applying skills developed in the classroom, and collaborating in project teams of 3-4 students, the first-year students designed and built six unique and creative interactive displays.
- Simple Machines – A local client, the Woodland Montessori School, partnered with the first-year students to develop simple machines for teaching children concepts in science and engineering. In teams of 4-5, engineering students designed and produced systems composed of simple machines that were similar to the Rube Goldberg Machine concept which either introduced or help to explain

concepts taught to second grade aged children. Students followed the Human-Centered Design process taught in ENGR 101 and incorporated physical and analytical prototyping and engineering fundamental analysis to provide evidence for decisions. Embedded in the project were engineering decisions that included but were not limited to safety considerations, educational merit, sustainability, cost, desirability, and scale-up challenges.

- Solving Big Problems for Tiny Houses - Teams of 3-4 students analyzed challenges and design solutions associated with Tiny Houses to serve the needs of their clients, a local family of four, who want to downsize to a tiny house. Tiny Houses are residential structures of approximately 150-400 square feet that can be either permanent or on wheels; they can reduce environmental impacts of residential living and make home ownership more economically viable. Over the course of the semester, the teams used creative and analytic problem-solving process to tackle: space efficiency, heating/cooling of the house, renewable energy, waste management, and innovative materials. All of these challenges involve safety, health, affordability and legal dimensions as well. Students used information literacy skills, field trips to a tiny house and to a residential green building, and engineering fundamentals to analyze the problems and justify decisions that led to potential solutions. For the space "problem", each team designed and built a "furniture" prototype that met at least three client needs.

The semester culminated in a project presentation during the department wide end of the year showcase entitled, "Madison Engineering xChange." The Madison Engineering xChange brought together students, faculty, staff, parents, friends, external partners, and the interested public to share student projects and accomplishments from the 2014-15 academic year. During the xChange, first-year teams demonstrated their project solutions and had the opportunity to interact with their clients and other members of the Madison Engineering community. They also had the opportunity to learn from their classmates in the other 112 sections – how did the different project teams apply the same fundamentals to solve very different problems? In addition, first year students explored course, capstone, and honors projects completed by upper level students. The event is an opportunity for first-year students to preview what is to come in their undergraduate engineering academic careers but also a chance to ask questions and challenge the upper level students.

Madison Engineering Residential Learning Community – ENGR 280 courses

The Madison Engineering Residential Learning Community (MadE RLC) was designed to engage a select few first-year engineering students who applied to participate in the residential learning community. MadE RLC is a unique opportunity to live, learn, and lead with a small group of students who share a spirit of inquiry, contribution, and excellence. The year-long experience allows students to live, study, and socially interact with their engineering peers, peer-mentors and instructors. The MadE RLC provided access for students to create special connections within the department, college, university and the community at large.

Through MadE RLC-only activities, students have the chance to gain the skills necessary to become a leader within the learning community and beyond, potentially launching their engineering careers on a pathway to success. Students were presented with opportunities to apply classroom knowledge alongside faculty and staff outside of the traditional educational environments and participate in extra professional activities while positively affecting the world.

Fifteen students were accepted to be a part of the inaugural cohort. The members were separated into three project teams. The course met each week and students presented progress updates every third week. MadE Leadership Mentors were involved in the course where two mentors were assigned to each team to be a resource and to assist with coordinating resources.

The specific goals of the MadE RLC are as follows:

1. Gain access and connection to the Madison Engineering Community by understanding attitudes and expectations of being a Madison Engineer.
2. Cultivate the abilities to frame problems and create solutions ideas within a set of defined constraints related to time, material, personnel, and problem parameters.

The MadE RLC course (ENGR 280) offered in the fall semester was a project-based one credit hour course that provided experience with systems and design thinking that also prepared the students for ENGR 112. The course is also meant to be complimentary to ENGR 101, while diving deeper into topics. The course objectives are the following:

Upon successful completion of this course, the first year student will be able to:

- Increase their self-knowledge and begin to develop into productive academic partners. *(ABET i)*
- Establish effective working relationships with supervisors, peers, and others. *(ABET e)*
- Engage in self-regulated learning. *(ABET i)*
- Gain awareness of processes and be able to construct diagrams of situations based on systems thinking and explain the variables and feedback

loops inherent to the system given data compiled about a given situation. *(ABET c)*

The course project was the Bio-Inspired Design Quest, which required teams to provide a solution to a learning issue that is prevalent for 2nd graders in the Rockingham County/Harrisonburg Community. The constraints were that the solution for the 2nd graders must be embodied in video game using an online gaming system platform, the MaKey MaKey interface system, and the game environment must mimic systems found within an arboretum eco-system and fall within the "laws of nature." Guests from the community that taught second graders or prepare teachers to teach second graders were invited to attend the course periodically throughout the semester. The semester culminated in a project presentation with community members invited.

The MadE RLC course (ENGR 280) offered in the spring semester was a one credit hour course that focused on self-regulated learning in order for the students to develop their academic and professional personas in a practical manner. The course also utilized a work-integrated learning approach to expose students to the different aspects of engineering. The course objectives are the following:

Upon successful completion of this course, the first year student will be able to:

- Engage in self-regulate personal and professional development. *(ABET g, i)*
- Create and maintain an ePersona that establishes a Madison Engineering identity. *(ABET f, g)*
- Conduct themselves in an ethical and professional manner in a variety of professional settings. *(ABET f)*

The course project was to create an ePortfolio, which required individuals to create an electronic online professional persona (ePersona), a personal professional website, a resume and artifacts that represent their skills as a developing Madison Engineer.

The course met each week with instructors, MadE Leadership Mentors (two individuals were assigned to the course) or guest lecturers/facilitators. The activities within the course were related to three different module sets: Career Fair Interviews, Professional Persona Development Workshop Series (joint venture between Digital Communication Consulting and Career & Academic Planning), and the Guest Lecturer/Facility Tour Series.

The Career Fair Interviews module had each student create a profile within the Career & Academic Planning portal and find companies that would be present at the career fairs during the spring term. Students were instructed to select three companies and conduct research about each company prior to going to the career fair. Each student had to interview company representatives about what the company looks for in the materials prepared by applicants. Sample questions are as follows:

- Tell me about your company's culture? What does your organization emphasize?
- How do JMU graduates stand apart from other universities where you recruit? What are some suggestions on how I can display that information in my documentation?
- What kind of experiences (internship, research, coursework, etc.) do you find most beneficial for applicants applying to your organization?

Once the data was gathered the students wrote a reflection paper on the experience and information provided by employers in the attempt for the students to gain an understanding of how the information will help them in future. The instructors also had a debriefing session to discuss experiences of the students in an open forum.

Professional Persona Development Workshop Series was a joint effort between Digital Communication Consulting and Career & Academic Planning. The workshop series offered the students a series of five workshops across the semester to help them develop an ePortfolio and refine interviewing skills. The workshop series titles are as follows:

1. Introduction to ePersona
2. ePortfolio Creation Workshop
3. Resume Workshop
4. Interview Skills
5. ePortfolio Utilization Workshop

The final deliverable for the module was for each student to schedule their own mock interview with the Communication Center based on an actual job posting found within the Career & Academic Planning portal. The exercise was meant to allow the students to practice their interviewing skills and utilize their ePortfolio during the interview. The interviews were a minimum of 20 minutes and recorded.

Guest Lecturer/Facility Tour Series encompassed two facility tours (James Madison University Power Plant and Dynamic Aviation) and two guest lecturers (one representative from Moseley Architecture – Sustainable Design Projects and one representative from Merck & Co., Inc.). The MadE Leadership Mentors were responsible for scheduling the majority of the aspects of this module.

CONCLUSION

This paper describes the structure of the Madison Engineering First-year experience. The motivation of the reimagined first-year experience was to help retain students through a learner-centered pedagogy while providing them with authentic, experiential, project based learning experiences. These experiences helped facilitate first-year students in making their transition from high school to college and equip them for success as students within the department and beyond.

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