Modules for Innovation and Entrepreneurship in Existing Curricula

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Abstract

The progress done towards implementing an integrated approach to innovation and entrepreneurship in existing engineering curricula is presented. These efforts are based on the fact that the knowledge and skills for the future workforce of an energy efficient, sustainable industrial and entrepreneurial society are not fully nurtured in current educational programs. These topics, together with innovative design practices, need to be an essential part of the learning experience in undergraduate engineering technology programs. The proposed integrated approach teaches the basic theoretical knowledge and hands-on practices of the aforementioned subjects embedding modules in a sequence of courses across the curriculum. The main objectives are: (a) introduce the entrepreneurial process and practice in a multidisciplinary environment, (b) emphasize energy efficiency, environmental friendliness, and long-term sustainability in fundamental engineering courses, and (c) apply the proposed approach in the context of human-powered transportation systems, a topic that has great interest and potential in underdeveloped countries. The work included in this project is the definition of the modules and their content, and the labs, projects, practices that are recommended for implementation. This project is partially funded by an NCIIA planning grant, and it is expected that it will serve as a model for integrated modification of design in engineering technology programs.

Keywords: Innovation, Entrepreneurial, Engineering Technology.
INTRODUCTION

For highly competitive and globalized markets there are a plethora of technical and humanitarian methodologies and philosophies that have been developed or implemented [Gra], all of them with the goal of providing a competitive advantage to its adopters, or having a well-rounded professionals for today’s world. Among those concepts, of significant relevance and usage are topics such as: innovative design, social engineering, energy efficiency [McL], eco-friendliness, human-centered, entrepreneurship, sustainability, and service learning. Each one of these concepts provides a new perspective to the typical way of developing new products or services, and therefore it is imperative that educational institutions adapt their offerings in order to form and cultivate the professionals that are, and will be, needed to address the world’s issues.

The aforementioned topics have received significant attention for couple of decades [Del, Had] with perhaps sustainability and entrepreneurship having more recent thrust over energy efficiency, ecology, and design innovation. Accordingly, in pursuit of their objectives, universities [Dav] and industries [Joh] have undertaken many efforts in those areas. In academia [Gau], freshman-level courses [Pos], majors [Des], multidisciplinary courses [Sko], specializations [Wes] and master’s programs [Tho] are some of the activities that have been undertaken.

This work focuses on introducing some of the listed topics in a sequence of existing courses, from second year to senior year, in two engineering technology curricula. The topics that will be emphasized are:

- **Innovation** in design can be considered as one of the responses to the needs in today’s world. Design innovation usually leads to product and process innovation, which in many cases serves as a venue to address efficiencies. Design innovation has a bidirectional relationship with technological and industrial innovation: there is the type of design innovation that is motivated by some new technological or industrial innovation, and there is the type that produces or leads to technological innovation. The latter being the riskier and costlier, from the entrepreneurship perspective, but at the same time the one with the greater impact potential. A Re-Design approach, where there is a mixing of new ideas with existing ones, will be pursued in the proposed work.

- **Entrepreneurship** is a field that has evolved, again, from the needs in today’s society/world. This field has elements from innovation, leadership, economics, management, and it can focus on social responsibility and other areas, and it is one of the fast-growing fields in higher education. Some stages of the entrepreneurial process emulate a standard engineering design process (e.g., need identification, planning activities), but at the same time it implies the use of other concepts while pursuing the identified opportunities. Entrepreneurship implies more than coming with an efficient or inexpensive solution, it comprises establishing a better entity to support the needed system. This aspect is one of the implementations that the proposed work will embed into current curricula.

- **Energy-efficiency** is a criterion of great relevance for today’s society. This topic is part of the larger field of sustainability of a product or a process, and its importance is due to its relationship with the use of available resources. Although the subject of energy efficiency is addressed in various technical courses, generally it is not the most important factor in the overall design of a product or process. The issue of energy is generally one of many other design factors under the concept of cost of design and manufacturing. The propose work will focus on the need for deeper understanding of the effect of energy efficiency on component/system design, and their long term sustainability.

To provide the knowledge and skills necessary for the workforce of the future, existing programs in higher education need to incorporate these topics and practices into the curricula. In most engineering technology programs, the topics are introduced informally in one or more courses.
without meaningful integration in the program, or between them. These topics are essential element of learning in the engineering field, and an integrated approach to embed such concepts and practices into existing courses, from fundamental to senior-level, and projects is a prudent alternative for reforming engineering technology curricula.

This paper presents an initiative for curriculum reform via an integrated teaching of innovative design, entrepreneurship, and energy efficiency concepts, in a sequence of courses from engineering fundamental to capstone design. The topics will be introduced by the use of newly developed materials for lectures and labs in standard courses, and then students will apply this learning in design projects that will focus on human powered transportation system (HPTS).

2. Background and Context

At the undergraduate level, in the College of Engineering and Applied Sciences (CEAS) at XXXXX University there are twelve engineering and three engineering technology programs, all of which are accredited by the Accreditation Board for Engineering and Technology (ABET). The Department of Industrial and Manufacturing Engineering (IME) houses the three engineering technology programs (i.e., Engineering Design Technology, Manufacturing Engineering Technology, and Engineering Management Technology) and one engineering program (Industrial and Entrepreneurial Engineering). Based on the input from Industry Advisory Boards, faculties, students, alumni, and employers, these programs have gone through substantial revisions in the past years. The first major revision was converting the former Industrial Engineering (IE) program into Industrial and Entrepreneurial Engineering (IEE) in 2006, followed by changing the old Engineering Graphics and Design Technology (EGR) program into Engineering Design Technology (EDT) in 2010. The Manufacturing Engineering Technology did not change name but had several changes approved in 2010 as well.

The new IEE program is of great significance to this project. For entrepreneurial content, the approach followed was to create a sequence of three new courses (Entrepreneurial Engineering I, II, III – sophomore to senior years), and after two graduating classes, the approach has been improved. Faculty members teaching those courses are a valuable resource in our project of infusing entrepreneurial concepts into the engineering technology curricula. Their lessons learned and insights will be a great help, and this is a continuation of the collaboration started years ago to include design concepts in the new IEE program.

In the engineering technology side, there are several proposed changes that support well this project because involve some of the courses that are being used in the integrated approach:

a) inclusion of lab experiments in courses dealing with fundamental concepts. IME2830: Thermodynamics (in process), and IME3840: Fluid Mechanics and Hydraulics (implemented)

b) new introductory course dealing with the professional practice of conceptual design, including social and economic motives. IME1430: Product Design Fundamentals (implemented)

c) new course that focuses on advanced technologies and approaches to product design, with emphasis on its lifecycle. IME4490: Advanced Product and System Design (in process)

d) new course covering sustainability but with some aspects of eco-friendliness and social responsibility. IME 4570: Manufacturing for Sustainability (implemented).

The field of human-powered transportation system (HPTS) is the selected theme for the subsequent student project work. In the context of rising energy cost and environmental concern due to fossil fuel use, this is an excellent opportunity to apply the embedded topics, and at the
same time address the problem a current socio-economic problem. The students involved will have a great opportunity to learn about alternative sources of energy and energy efficiency, while practicing innovation, entrepreneurship and sustainability. As background, WMU has participated for several years in two student-competition projects: i) Sunseeker, the solar car competition, and ii) Chainless Challenge, a competition where students design chainless human powered vehicles (bicycles). Both projects have been under the supervision of the IME department, and the co-authors have actively participated in both of them.

3. Work Plan and Outcomes.
This project has a three years span for development and implementation, and it started in 2011. It is divided in three phases:

- **Phase I. Fundamentals.** Referring to courses dealing with engineering fundamentals at sophomore and junior years. The courses are Thermodynamics and Heat Transfer (IME2830) and Fluid Mechanics and Hydraulics (IME3840)
- **Phase II. Design.** Referring to courses dealing with engineering design at junior and senior years. The courses are Product and Machine Design (IME3440) and Advanced Product and System Design (IME4490)
- **Phase III. Projects.** Referring to courses suitable to undertake semester or year long projects, at senior year. The courses are Multidisciplinary Senior Design Project (IME4910, 4920, 4930) and Undergraduate Research/Independent Study (IME4980 and 4990).

Each phase of the project corresponds to one year of duration. This is a natural process given the proposed approach of building knowledge in a sequence of courses. During Phases I and II students are to the concepts of innovative design and entrepreneurial process, with emphasis on energy efficiency. Then, in Phase III students will be working on the specific project of developing HPTS.

The work procedure for Phases I and II is basically the same since it implies embedding selected concepts, in a modular fashion, in existing courses. The procedure is:

a) develop a list of resources and notes that will be used as pedagogical and reference materials
b) develop and prescribe lectures and lab, and their corresponding assignments
c) plan complementary activities (e.g., guest speakers, case studies seminars)
d) evaluate, assess and revise developed materials and implementation procedures.

In the modified courses, laboratory exercises are designed to reinforce student learning in the classroom through hands-on practices. To ensure effectiveness of student learning, a combination of lecture, problem solving, and laboratory exercise, case study and investigative report are planned/implemented.

A summary of objectives and plans for the four existing courses being used as testbed is given below. The goals are to infuse the proposed concepts in each one of the courses, and prepare the students to apply them in the context of HPTS. Accordingly, the

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<th>Phase</th>
<th>Course</th>
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<td>I</td>
<td>Fluid Mechanics</td>
<td>Energy efficiency, innovation, HPTS</td>
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<td></td>
<td>Thermodynamics</td>
<td>Energy efficiency, innovation</td>
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<td>II</td>
<td>Product Design</td>
<td>Innovation, Entrepreneurship</td>
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<td></td>
<td>Advanced Product</td>
<td>Innovation, Entrepreneurship, HPTS</td>
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For Phase III, project-based courses will be utilized. Prior to graduation, CEAS seniors are required to complete a Senior Design Project, a two-semester team project for design and development of a product or process. The senior projects are proposed by the faculty and the students bid on them. Most of the projects are industry sponsored, but there are faculty sponsored projects. Participation of students in projects such as Sunseeker, Chainless Challenge, and SAE
Formula is consistently done through senior projects. Although a senior project during year 3 is the culmination of the proposed work, an initial senior project will be run during year 2 in order to introduce HPTS to students. Some of these projects have been assigned to senior groups in order to have a baseline for comparison once the full project is implemented. In this first year there were two projects that had to deal with HPTS, a cargo bike and a hydraulic bike.

**Outcomes.** The main outcomes of the proposed work are:
- valid alternative approach to infusing specific topics into existing courses, an approach that integrates the new materials into a common goal
- HPTS solutions that will have a social and economical impact in underdeveloped regions
- better prepared students with a global and entrepreneurial perspective, thus resulting in better professionals
- deliverables consisting of the materials developed for the introduction of each topics being infused.

The work certainly is a challenging project, but based on the support, commitment and timing of the project, it is expected to have invaluable benefits.

**E-team.** The concept of E-team is a terminology used by NCIIA to refer to teams dealing with entrepreneurial concepts. The authors, which are the faculties mainly responsible for the courses were the project is implemented, are leading the efforts and coordinate activities to accomplish the proposed changes. Each faculty is directly responsible for two of the courses that will be modified, and they are actively involved in capstone design projects, student-competitions, and undergraduate research. The E-team, where E stands for excellence and entrepreneurship, will be formed at the end of the courses in Phase II. The students will be invited to apply in the HPTS project during Phase III, and team members will be hand-picked based on their course performance and motivation to participate. The expected pool of potential team members is 25 students (typical enrollment for junior level courses). The team will have between 6 and 8 members, given the expectation of the project. Team building concepts, together with collaboration protocols, will be emphasized in the regular lab activities during Phases I and II.

In Phase III the team will need to form a broader investigative team with support from SBA agencies, and eventually with industry sponsors/partners. Communication protocols will be developed using Google tools, where each team member can retrieve and update work documents/files irrespective of physical location, and can maintain online communication. This will also serve as archive for project documentation, an important aspect in case of an Advanced E-Team grant application.

For the duration of the project the external support for entrepreneurial activities will come from SBA agencies. In case of successful results, support from the Office of VP for Research (WMU) and Southwest Michigan Innovation Center (Michigan First), both facilitate commercialization of invented intellectual property. After review of any invention for patentability, practicability, market potential and need to IP rights, these offices might help to find investors or corporate partners interested on the new IP. Any new technology or innovative product resulting from the proposed effort will be commercialized upon such review.

**4. Planned Activities**

In this project there will be an evaluation process that will provide immediate feedback from the students and other parties involved (e.g., faculty, industry consultants, speakers). This process will be survey-based and it is based on the objectives define for the implementations in each course at each one of the phases – particularly for Phase I and II. For these phases, we will have the opportunity to make modifications and improvements before the next offering of the course.
In terms of overall impact of the changes in fundamental and design courses, the collected data will be compared to current course evaluation data in order to identify strengths and weaknesses of the new contents.

For Phase III, an expectation/satisfaction evaluation will be applied. In this case it is more problematic to do comparison to previous offerings due to the nature of the projects. The more important assessment will come 3 years after the project is implemented, when we have our next ABET accreditation visit. On one side, Industry Advisory Board, alumni and employers are surveyed, and on the other side, ABET visitors will review the effectiveness of the modified curricula.

This project has had the full support from the department and the college. There are several activities going on in the college and the department that it just makes sense to undertake this project at this point. The expected benefits are tremendous; therefore, sustaining the implemented plan is not an issue. We have the resource of IEE faculty; interaction with student-competition projects and their list of donors and; access to expertise from the Green Manufacturing Initiative, Office of Sustainability, Innovation Center, and Michigan Small Business and Technology Development Center. Additionally, the authors are faculty members that have been actively involved with senior projects and are directly responsible for the fundamentals/design courses being modified. The institutional support includes space and access to labs and technicians. This is already the way senior and competition projects are run. For office space, one co-author (Rodriguez) is co-director of the Center for Integrated Design (CID) where students have access to workspace, computers and small prototyping and reverse engineering equipment.

5. Progress

At this point the project is in its second year of development and implementation. The expected sequence of the three phases has been partially followed because some projects have taken place. Three different courses, namely, IME 2830 (Thermodynamics and Heat Transfer), IME3840 (Fluid Mechanics and Hydraulics) and IME4490 (Advanced Product and System Design), have been upgraded to incorporate concepts (and lab experiences) mainly in energy efficiency. The elements used for the emphasis on energy efficiency are fluid power/control components (e.g., valves and piping systems). The hands-on activities have received good feedback from students, helping them in learning about applicability of energy-related concepts presented during lectures.

The initial concepts on innovation have been implemented in the senior level course (IME4490), which was offered for the first time last semester. This topic was emphasizes with exercises on brainstorming and research and improvement of existing solutions. These exercises take place during the assigned 3-hour lab period, and have been a drastic change from the expectation from the students to have a typical lab session. The feedback has mostly positive, with some reluctance to accept assignments with “correct solution”.

Senior projects have been conducted, and has been a good platform to emphasize two topics: human powered transportation systems, and entrepreneurial concepts. One senior design team selected to do the work needed for participation in the Chainless Challenge. A four-student team carried out design, fabrication, assemblage and testing of a bicycle based on hydraulic components. For the entrepreneurial aspect, there were required to do a cost analysis (concepts covered in regular curriculum) and to investigate the feasibility of launching a new product (concepts delivered as project progressed) to the market. The team performed very well. The other senior group has been working on a human-powered cargo/people vehicle, project that ends this semester.
Even though the timing of this project has not followed the defined sequence, they have been good experiences to provide information and familiarize students in the two mentioned topics.

6. Conclusions

The progress of this project, basically Phase I and part of Phase II and Phase III activities have shown positive outcomes. No formal assessment has taken place, due to the fact that there is only one senior project that has been finalized (one is being finalized this semester). Being this a Course and Program project, the emphasis will be the process followed and the value of the integrated approach. It is expected that this approach of infusing innovation, entrepreneurship and energy efficiency in a series of courses, instead of creating new ones, will be of great interest. All aspects of the process will be documented, and offered as guidelines for future endeavors similar to this one. An additional benefit to this work is the use of this project as a marketing and recruiting tool, during open houses, tours, and middle/high school summer camps. Showing something being built is always a big attraction, as our experience with other student competition projects indicate.

6. References