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Delivering Leadership, Innovation and Entrepreneurship Concepts in a Typical Manufacturing Course

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Introduction

Tennessee Technological University (TTU) - College of Engineering has a newly developed Strategic Plan that is defined as 21st Century Renaissance Engineers Revolutionizing Engineering to Solve Societal Problems. A 21st Century Renaissance Engineer brings innovation to both problem solving and technology that helps to make the world a better place. It is expected that TTU engineers will go on to be industry leaders, innovative business owners, and successful entrepreneurs.

The goal of the project reported in this paper is to prepare engineering students in three key components of the college strategic plan: 1) leadership in industry, 2) innovation in business, and 3) entrepreneurial success in engineering. These components are all being implemented in a junior level manufacturing course, CNC Machining Practices. This course is an industrial programming course for automated machining systems like milling and turning. Students learn and practice coding, simulating, and real machining of industrial parts and components. This course is a required curricular course for engineering technology majors and is offered almost every semester.

In this project, course students have opportunities to attend guest lectures from industrial representatives and expert business/engineering professors on these three topics, and to work on team-based product development projects. Finally they enhance their critical thinking and real life problem solving skills throughout the course and project.

CNC Machining Practices include active learning and teaching with technology techniques that will increase interaction among students, faculty, and guest speakers; i.e., Clicker Tools, Socratic Questioning, Gallery Method, Service Learning, and Studio. At the beginning of the semester, four industrial projects are developed and assigned to student teams of five students each. Teams have mentors from industrial representatives, College of Business faculty, marketing professionals, and regional engineering firm leaders/managers. Teams practice the three knowledge sets they have learned with real industrial projects. Teams specifically report how they have solved their problems and enhanced their skills in 1) leadership in industry, 2) innovation in business, and 3) entrepreneurial success. At the beginning of each lecture and laboratory practice, a team-time section allows issues faced by the teams to be solved immediately. Individual team times and office hours are also held twice a week.

Students' progress on learning and practicing the core project deliverables is evaluated using a short pre- and post-survey provided by the QEP (Quality Enhancement Plan) Program that includes questions modeled on items from the NSSE (National Survey of Student Engagement). The NSSE items also relates to critical thinking, real-world problem solving, teamwork, and service to the community and profession.

Background

Creating challenging minds in Innovation, Leadership, and Techno-entrepreneurship has been gaining attention in the 21st century's engineering and business teaching and practices. Many

higher educational systems have developed degree programs, minors, certificates, and concentrations to provide solutions to the need of today's market demands. In literature, many undergraduate and graduate courses are designed on these topics covering: 1) developing and setting goals and objectives, 2) developing and implementing a healthy business model, 3) establishing growth strategies, 4) key features of a successful leader, sustaining business, and marketing management, 5) establishing financial stability- approaches and strategies, 6) identifying channels to reach customers, 7) developing continuous and sustainable customer relations, 8) developing strategies for business growth, 9) how to develop cash-flow, capital investment needs, income-expense tables, cost-benefit analysis, and marketing strategies, 10) advancements in product development, analysis, and simulation, 11) advancements in production technologies: additive versus subtractive, impact of outsourcing, and cost analysis, and 12) hands-on tips on initiating communication with investors. The new approach focused in this study was to establish a framework integrating all these components into one unique manufacturing course. Figure 1 provides the linkage among these three factors covered in this course.[1]

Figure 1: Innovation, Leadership, and Entrepreneurship Framework

To cover the fundamentals of these concepts in engineering, business management, marketing, finance, and entrepreneurship, a series of guest lectures has been developed and added to MET3060 starting Fall 2014 semester. In the newly revised MET3060-CNC Machining Practices course, students learn the technical concepts and non-technical lectures have been provided by subject matter experts. This course has been revised in the past and additional web-based delivery modules have been added[2-3]. In course lectures and laboratory practices, guest lectures, and course projects, special emphasis has been given to critical thinking, real-world problem solving, teamwork, and service to the community and profession. Biweekly organized team time meetings have provided an ideal opportunity for students to question the problems and issues they face in the lectures, laboratories, and team projects.

Lecture and Laboratory Sections

During the semester, weekly technical lecture and laboratory practices have been provided on the conventional CNC topics. They are 1) Introduction to Computer Numerical Control, 2) Fundamentals and Vocabulary, 3) Programming Concepts, 4) Interactive Simulation Tools in

CNC, 5) Advanced Milling Programming and Practices, 6) Advanced Turning Programming and Practices, 7) CAD/CAM Concepts, and 8) Industrial/Societal/Real World Projects.

MET3060[4] students gain a number of technical competencies in this course: 1) define CNC, CNC system components, media input/output and storage of CNC programs, 2) comprehend the control systems, tool selection/movement, and work piece selection, 3) explain components, functions and operation of machining centers and the Machine Control Units, 4) perform mathematical computations for CNC Programming, use of programming terminology, and G & M machine code systems. 5) provide an overview of typical machine shop practices, as well as CNC programming and setup operations. 6) work on an industrial term project and write report and present their accomplishments, and 7) communicate more efficiently.

Educational Innovations

Hybrid manufacturing integrating both additive and subtractive technologies is getting extremely popular in the 21st century.[5] Although additive manufacturing is an elective course in the engineering technology curriculum, MET3060 CNC Machining Practices is one of the required courses and it is offered in all semesters. Students learn the fundamentals of subtractive machining technologies first, and then advance quickly with the use of programming and simulation tools. Hands-on milling and turning practices are the essential part of this course. Student teams design and fabricate a number of real-world machining projects at the end of the semester.

This course is one of the best engineering courses in order to implement the innovation, leadership, and entrepreneurship concepts in the entire curriculum, and it challenges students to grasp a number of industrial soft skills such as problem solving, team work, and analytical thinking.

Although some of the course students find jobs as programmers, machine operators, tool designers, and manufacturing engineers, the number of students with a mindset in creating jobs with the latest trends supports the National Network in Manufacturing Innovation-NNMI initiative[6-7] is still extremely minimal. The course structure focuses on gaining self-awareness of professional motivations and provides a knowledge set of the latest innovations, advancements, and entrepreneurship concepts in today's manufacturing field overall. Guest lectures provided throughout the semester focus of these key deliverables.

A number of tools in teaching with technology is also practiced in MET3060. They are listed below:

- Classroom Response Systems known as Clickers are frequently used to receive quick feedbacks from course students. Such tools are also efficient to keep students focused on lecture topics and laboratory practices.
- G and M functions are learned and practiced throughout the course. These complex functions are hard to grasp and understand. Memorization of these functions are not recommended. After the lecture about each function, students are encouraged to run a demo code from the course simulators and to discuss their complex run with the entire class in Socratic Reasoning.
- In MET3060 course, students generate creative milling and turning codes during the course practices and final projects. The best ones are displayed on the walls and shared

with the other course students. Students' best codes and finished products are kept on the wall until the next projects.

- Societal Problem Solving is an important part of today's educational practices. Exposing students to the actual world makes them engaged into the problems of real life. MET3060 students usually receive STEM and Environmental projects from local educational agencies and industries and try to solve them as their final project.
- Studio methodology integrates the course deliveries in lecture and laboratory. MET3060 students keep themselves engaged in course content deliveries and practice milling or turning technologies at the same time. Such a unique practice makes them fully knowledgeable about the content and its real consequences.

Guest Lectures

In addition to the regular technical course lectures and laboratories held in the MET3060 course, a number of guest lectures have been provided to course students. Brief summaries about their coverage are given below

Dr. Joseph Rencis, Dean of Engineering, talked to MET3060 students about the newly developed Strategic Plan and its importance. The Strategic Plan will ensure that majors in each engineering program will be successful in today's higher education system. Technology is evolving and becoming more sophisticated in the advanced world, and engineering departments should be held to certain standards to ensure that students are staying up-to-date in the needs and expectations of the global marketplace. The Strategic Plan provides direction at the university, college and student level to facilitate success in the marketplace. Dr. Rencis summed up his speech by providing questions and answers about the importance of the Strategic Plan. He emphasized the importance of creating a new race of engineers, the Renaissance Engineers, who are the cutting-edge engineers building the future.

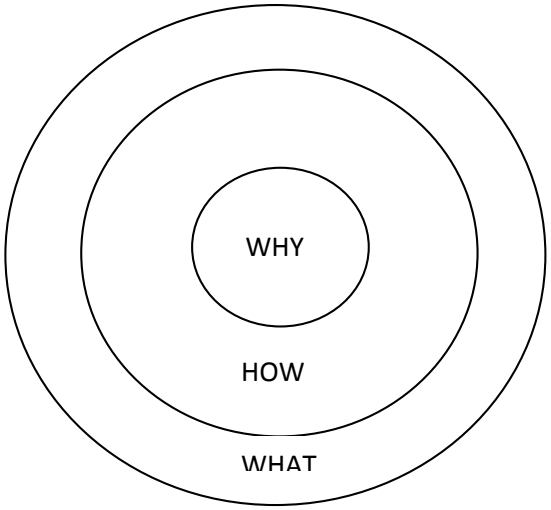
Dr. Lee Martin, Engineering Entrepreneurship Program Leader at University of Tennessee, Knoxville, talked to MET3060 students about the Business Model Canvas. He summarized the 21st century engineering entrepreneurship and business techonomics. He indicated two main reasons to start a new business: to satisfy a need that the society has and to make profit. In any business it is fundamental that the Reverse Stream is greater than the Cost Structure; in other words, the base is to make a profit. Reverse Stream refers specifically to the individual methods by which money comes into a company while cost structure refers to the types and relative proportions of fixed and variable costs that any business incurs. Today, Business Ecosystem is complicated since it is a highly competitive world. Everybody wants to sell products with a lower price than the competitors' price, so technology plays an important role in today's business world. The companies practicing the latest technological tools and trends usually keep the highest places in the market share of their products. Dr. Lee Martin explained the relation between business and technology clearly with his term, Techonomics. This relationship is thoroughly explained in his book by the same name.[9] He explained the concept of Techonomics with examples from his book.

Dr. Bonita Barger, Associate Professor of Management at Tennessee Tech University, asked MET3060 students whether they thought that they were creative. She then gave each student a piece of paper with five shapes on it and told each to pick the one that is different from the others. The point of the exercise was to show that in life, there is more than one right answer. Since life isn't a math problem, where only one answer exists, students can be creative with

problems/situations. Dr. Barger later gave students another test based on several years of research to determine if an individual possesses the personality, attitude, values, motivation, and interests that make up creativity. The idea behind this test is that people who think they are creative generally are creative, and those who think they aren't creative are usually not. She has provided research-based case studies and published articles from current journals and newspapers to explain how students grasp the innovation, creativity, success, and failure concepts in real life scenarios.

Mr. Ralton Emory, Manager of Industry and Member Relations at SME, returned to his alma mater to talk to current MET3060 students. He indicated that manufacturing engineers touch everyday life more than any other kind of professional does. Everything that we use is manufactured or processed. It is very important to think about the why of design and manufacturing. When planning to design a product or make a company, one should decide why it is necessary to make this product or company.

Then, he explained the Why Circle logic as given in Figure 2.



When you produce something, you make a what. The actual product is the what. Then it is necessary to think how you are going to do this product or how it is going to work. The why refers to the heart of this logic: the people.

Figure 2: The Why Circle Logic

Dr. Niaz Latif, Dean and Professor at Purdue University, provided an advanced teleconference lecture to MET3060 students. Dr. Latif divided his teleconference into four parts: innovation, entrepreneurship, engagement with industry, and professional development. These points are the most important of the strategic plan of the School of Technology at Purdue University/Calumet. He indicated that to make an innovation in the manufacturing field, it is important to have a clear understanding of the four general areas of manufacturing.

- Materials and processes
- Product, tooling, assembly-related engineering and technology
- Systems and operations
- Competitiveness: quality assurance and quality control, global competitiveness

Dr. Latif presented the importance of entrepreneurship in the engineering field. He said what could be a great opportunity to think about starting a company in a potential place of the market. An innovative person will always find an opportunity to be an entrepreneur.

Assessment and Evaluation

MET3060 students took a survey at the beginning of the course and at the end of the course. The questions in these surveys are given at Figure 3.

There were 15 feedbacks provided for the full analysis of the course practices. The other five students in the CNC Manufacturing Practices course either did not do the pre-project online survey or the post-project survey, or they did the pre-project online survey more than once and had different responses to the questions; therefore, the evaluation of their surveys was not considered in the evaluation and analysis.

MET3060 students on average replied that they made more progress in this class compared to their typical TTU classes on the 19 topics. These results are significant at the 95% confidence level, using a 1-sided t-test. The 1-sided test is appropriate since by conducting the project, the course intended to improve students' reported performance on each of the 19 topics listed compared to a typical TTU class. The results indicated that the course needs improvement in questions 4, 8, and 10. However, significant progress has been made on questions 12, 13, 14, and 15, which are the core deliverables of Quality Enhancement Program of the University.

Students also provided some written feedback at the end of the course. The following are two sample feedbacks reported by the course students.

Student 1: Overall I thought that this course was great insight on what we have to look forward to in our future careers. Merging the technical fundamentals with business concepts, real world practices, and expert talks was wonderful. Dr. Rencis presented on how the college of engineering has planned for our majors' cutting edge strategic plan overall. I have learned the importance of strategic planning in any business initiative. It was also great to hear that our school cares about the improvements of engineering departments. Dr. Barger was a great source for shaping our minds in creative thinking and the importance of innovation. She made us think differently and challenged us to be creative. Creativity is truly a priceless tool. Practicing Techonomics can set you apart from other competitors, which Dr. Martin preached. He wanted us to find our uniqueness, which is similar to being innovative. We got to see how far we could stretch our communication measures by having a conference call with Purdue University professor, Dr. Latif. He presented his solid knowledge and experiences on the importance of innovation, entrepreneurship and manufacturing market trends. Mr. Emory presented us a great insight on what we could expect to face in our future and careers. Troubleshooting is a main task for engineers, especially in manufacturing. I would like to thank TTU to exposing us to this information from true leaders.

Student 2: I want to say that I really loved the nature of this course. Lectures, guest presentations and real life project practices were great. Guest presentations were the excellent additions to this course. I think the topics that were treated in each of them are really important for all engineering practices today. The actual society requires innovative people who are brave and start new businesses since they are the real motor of any country. That is the reason why I believe that these topics should be a part of any engineering major, but normally, many professors do not care about them. Engineers are really perfect people to start a new business since their knowledge about technology and rational/analytical thinking is the best for the ground work of setting up an entrepreneurial initiative. I can say that these lectures and course practices I have gained were one of the most interesting things for me this semester.

	No Progress	Slight Progress	Moderate Progress	Substantial Progress	Exceptional Progress
1. Separate factual information from inferences.	O	O	O	O	O
2. Identify inappropriate conclusions.	O	O	O	O	O
3. Understand the limitations of correlational data.	O	O	O	O	O
4. Identify evidence that might support or contradict a theory or hypothesis.	O	O	O	O	O
5. Identify new information that is needed to draw conclusions.	O	O	O	O	O
6. Separate relevant from irrelevant information.	O	O	O	O	O
7. Learn and apply new information.	O	O	O	O	O
8. Interpret numerical relationships in graphs.	O	O	O	O	O
9. Use mathematical skills to solve real-world problems.	O	O	O	O	O
10. Analyze and integrate information from separate sources to solve a complex problem.	O	O	O	O	O
11. Recognize how new information might change the solution to a problem.	O	O	O	O	O
12. Effectively communicate.	O	O	O	O	O
13. Think critically.	O	O	O	O	O
14. Think creatively.	O	O	O	O	O
15. Solve real-world problems.	O	O	O	O	O
16. Effectively learn on your own.	O	O	O	O	O
17. Learning to analyze and critically evaluate other perspectives.	O	O	O	O	O
18. Learning to make effective decisions.	O	O	O	O	O
19. Working effectively with others as a member of a team.	O	O	O	O	O

Figure 3: Questions asked in the MET3060 Course Survey

		QA1	QA2	QA3	QA4	QA5	QA6	QA7	QA8	QA9	QA10	QA11	QA12	QA13	QA14	QA15	QA16	QA17	QA18	QA19
n =	15																			
df =	14																			
mean		0.667	0.733	0.933	0.267	0.800	0.867	1.000	0.357	0.714	0.533	1.133	0.800	0.733	0.933	1.000	0.400	0.786	1.133	1.467
stdev		1.047	1.534	0.961	1.486	1.014	1.187	0.845	1.447	1.204	1.187	1.125	1.474	1.163	1.033	1.558	0.828	1.311	1.187	1.598
SE		0.270	0.396	0.248	0.384	0.262	0.307	0.218	0.374	0.311	0.307	0.291	0.380	0.300	0.267	0.402	0.214	0.339	0.307	0.413
tstat		2.467	1.852	3.761	0.695	3.055	2.827	4.583	0.956	2.297	1.740	3.900	2.103	2.442	3.500	2.485	1.871	2.320	3.697	3.556
p		0.014	0.043	0.001	0.249	0.004	0.007	0.000	0.178	0.019	0.052	0.001	0.027	0.014	0.002	0.013	0.041	0.018	0.001	0.002
< 0.05?		1.000	1.000	1.000	0.000	1.000	1.000	1.000	0.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
mean>0?		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
both		1.000	1.000	1.000	0.000	1.000	1.000	1.000	0.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
product		0.667	0.733	0.933	0.000	0.800	0.867	1.000	0.000	0.714	0.000	1.133	0.800	0.733	0.933	1.000	0.400	0.786	1.133	1.467

Figure 4: Tabulated results of the MET3060 Survey results

Figure 5 shows the values in the Figure 4.

N	15
Df	14
Mean	Mean of differences of pre- and post-project survey response
Stdev	Standard deviation of all differences
SE	Standard error of the mean difference
Tstat	T statistic
P	P value using n-1 degrees of freedom
< 0.05?	If the p < 0.05 this value is 1 and the cell is shaded green
mean>0?	If the mean > 0 (meaning that your results were better than the average Tech class) this value is 1 and the cell is shaded green
Both	If both of the above cells are true then this cell is 1 and shaded green
Product	The mean value on questions for which the probability is significant at the 95% confidence level.

Figure 5: Values used in Table 4

Conclusion

Current research studies have shown that innovation, leadership, and entrepreneurship are becoming significant topics in engineering and business fields. Therefore, teaching these concepts is crucial because engineering educators prepare current and future generations of learners to recognize these topics and act on high-tech entrepreneurial opportunities. Education in innovation, leadership, and entrepreneurship may increase the knowledge of how to start one's own enterprise and recognize the technological opportunities for commercialization to improve decision-making about starting a new venture; also education influences decisions about capturing the business opportunities and turning them into successful ventures.

Higher education plays a key role in delivering these concepts in lecture and practice settings. This paper has reported the practices and enhancements made in an MET3060 CNC Machining Practices course. Technical topics were covered by course instructors. Subject matter experts in innovation, leadership, and entrepreneurship have provided in-depth lectures and Q&As to course students. The success of the practice has been measured with a pre-post survey instrument and feedbacks received from the students. Provided feedbacks showed that students appreciated the current enhancements. More lecture series and industrial projects are underway to increase the students' knowledge base in innovation, leadership, and entrepreneurship.

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