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EMPHASIS RELATED CAPSTONE CLASS: THE USE OF REAL-LIFE EXPERIENCE TO ENHANCE WORKFORCE READINESS

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ABSTRACT: *Preparing students for the workforce is one of the most important priorities in the education sector. The needs of industry are constantly changing and educators strive to find the best way to meet these needs. Providing a culminating experience in classroom settings is one strategy that allows students to apply the knowledge that they gained throughout their undergraduate coursework. This paper explains these efforts to develop a high-impact senior capstone course for Engineering Technology related majors. This research aims to explain a proven strategy for teaching this course after its two-year pilot phase. The course was created to address concerns of industry. The creation of an industrial environment in the classroom helps prepare students for the real world of work. This research is based on a course titled "Emphasis Related Capstone" (ERC), which is offered at Bemidji State University. The ERC course centers on product design and development and is used to prepare students for future careers. Steps for designing the capstone course are shared in this paper. Multidisciplinary teams (e.g. electrical manufacturing, design, project management) were formed to achieve deliverable outcomes. Examples of manufacturing projects conducted in the capstone course are also provided and instructors' responsibilities for teaching capstone courses summarized. In addition, a grading strategy for such capstone courses is provided.*

KEYWORDS: Capstone Course, Case Study, Applied Project Management, Technology Management, Workforce Readiness, Product Development

INTRODUCTION

The Emphasis Related Capstone (ERC) is a completely lab-based 4000-level capstone course designed to help students increase their practical hands-on activities and apply what they have learned throughout their undergraduate degree coursework. The class is required of all technology students and it is offered once a year in the Department of Technology, Art, & Design. The course is similar to an external industrial experience in that each student brings to the enterprise/class various skills, abilities, talents, and knowledge sets. Further, all students must work together, pooling their expertise, to achieve the final goal of producing a product that is a) of high quality, b) made to specifications, c) on schedule, and d) produced within a defined budget. Many products are developed in ERC, such as diploma frames, clocks, decorative items, and others. There are four to five groups involved in ERC, and each group consists of seven functional departments:

manufacturing and production, design, quality control, sales and marketing, purchasing, safety, and packaging. Each department should contribute to the process of developing at least one product. Machines that are available in the labs include planers, a laser epilog, a Kongsberg packaging cutting table, belt sanders, table saws, miter saws, routers, CNC, and speed sanders.

CAPSTONE IMPORTANCE

The US manufacturing sector faces many challenges, including global competitors who provide better features of products or services (Center for American Progress, 2011). These challenges have created a lot of pressure on organizations to implement best practices in their operations. They, in turn, have reached to workforce educators to help them develop the future workforce. Industry representatives, for example, provide feedback through discussion sessions on what skills Engineering Technology (ET) students should have (The Quality Assurance Agency for Higher Education 2014, 2014). Educators, meanwhile, have found that the best to meet these needs is by creating capstone courses, which provide opportunities for students to integrate formerly disconnected knowledge and/or skills into a coherent format (Mosher & Ramaswamy, 2014). Through capstone experiences, students have the opportunity to make meaning of their education and experiences, to recognize their strengths and weaknesses, and to understand what gaps remain in their knowledge and skills (Miller & Olds, 1994). They can then apply this knowledge to address challenges that face them in the real world. This experience also helps student to develop critical thinking, creative problem solving, and effective communication (Paretti, Layton, Laguette, & Speegle, 2011). Implementing capstone classes in the ET curricula has many advantages, such as the following:

- Apply the knowledge gained throughout their undergraduate degree (Dutson, Todd, Magleby, & Sorensen, 1997);
- Equip students with employability skills (e.g. critical thinking, creative problem solving, and effective communication);
- Provide students with culmination of theoretical approaches and applied experiences (Todd & Magleby, 2005);
- Prepare students for graduate studies;
- Help students in the transition to the world of work;
- Link students to employers and alumni;
- Connect senior students to alumni and prepare them to become active alumni; and
- Help graduates earn higher salaries.

CLASS STRUCTURE AND ENVIRONMENT

In order to meet our local industry needs, a senior Emphasis Related Capstone course was created for the technology students in the Technology, Art, & Design department. The class provides a real industrial experience for ET students through lab-oriented activities allowing them to design and develop products. This class experience is similar to an industrial experience in terms of working in a team environment, developing high quality products, meeting a schedule, and working within a defined budget.

The class was offered two times over a two-year pilot phase before it was required class. Four students enrolled the first year the class was offered and thirteen the second year. Since it has

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become required for all technology students, a full class of 25 students is expected in the Spring of 2017. Four projects were developed during these offerings.

The environment of the ERC class is different from that of the traditional classroom since students are treated as employees in a manufacturing company. The class is held three times a week for two hours each day for 15 weeks. Orientation and training sessions are given in the first two weeks. In the orientation week, students are trained using team-building activities such as "Multiple Intelligences," which is recommended by industry representatives who indicated that their employees lose their jobs much more frequently for not being good team players than for any other reason (Kennedy & Nilson, 2008). This training helps students to understand their strengths and weaknesses through focusing on linguistic, musical, logical-mathematical, spatial, body-kinesthetic, interpersonal, and intrapersonal intelligences (Christison, 1999).
Figure 1 summarizes these intelligences.

Figure 1: Multiple Intelligences

Soft skills topics that are covered in the orientation week include the following: obstacles to effective team work, building communication skills, basic listening skills, and principles of negotiation.

Professional topics covered in the class include project management skills, time management, quality assurance, design process, process analyses, charts developments, time studies, jigs and fixtures design, documentation preparation, oral and written report presentation, safety and risk management, technical sales and marketing, budgeting, and scheduling.

The following – table 1 and table 2 – summarizes these topics:

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Table 1: Career success skills topics

Verbal communications
Reliability
Positive Attitude
Responsibility and Accountability
Problem Solving
Continuous Learning
Critical Thinking

Table 2: Product development topics

Project management skills
Production planning and control
Time management
Quality assurance
Design process
Documentation and report preparation
Oral and written report presentation
Safety and risk management
Technical sales and marketing
Budgeting
Scheduling

The class is offered once a year with an expected average number of 25 students ("employees"). The students are divided into groups of 5. Matrix structures are developed in the class to diversify the projects, with five functional areas used in the matrix organizational structure. **Figure 2** shows these five areas.

Figure 2: Organization Structure

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INSTRUCTOR RESPONSIBILITIES

The non-traditional environment for this course requires clarification of the instructor's responsibilities. There are six best practices that the instructor has to implement to achieve the best outcomes. First, there is identifying the learning outcomes. Instructors should identify 7-9 learning outcomes that can be achieved through the course. Developing these outcomes will help students to understand what they need to accomplish after finishing this course. Second, there is developing multidisciplinary teams to ensure the diversity of skills in each team. More details are provided in the team forming section. Third, there is developing the guidelines for the student projects, which include a resume presentation, a prototype report and presentation, a final report and presentation, and a daily blog assignment. The fourth responsibility is determining assessment strategies and criteria. An example of an assessment strategy is provided in the grading section in table 3. The fifth task is to provide effective feedback on student work. This is important because critical reflection provides students with the opportunity to understand their weaknesses so that they can strengthen them in the future. The last responsibility is to provide the opportunity for students to showcase their achievements through presenting their projects to a campus audience.

COURSE OBJECTIVES

The following are the goals that students are expected to meet by the time they finish this course:

1. Synthesize the knowledge learned throughout the college experience and bring that collective knowledge to bear in a simulated industrial situation.
2. Operate within the structure of a simulated manufacturing organization while performing all of the functions necessary to design, produce, package, and deliver a product.
3. Research and prepare (individually and with team members) a presentation based on course specific content following the requirements stated.
4. Examine and apply the principles of human relations and apply the principles of project management in teams.
5. Work with other students to create, design, purchase materials, manufacture, package, and deliver a high quality product within a budget, to specifications, and on time.
6. Experience the attendance and participation standards imposed by industry.
7. Experience and adhere to the safety standards required in an industrial setting.

CLASS ATTENDANCE POLICY

This course experience is similar to an industry environment and, therefore, the attendance policy is similar to that of industry. Students cannot accomplish the goals if they are not present or leave early. Each unexcused absence or tardy detracts from a student's final points in the following way. Three "tardy" or "early leaves" will equal one absence. If, at the end of the semester, a student has no unexcused absences, that student will receive 10 points for attendance. Following the progressive discipline principle, 1 ab = 9.5; 2 ab = 8.5; 3 ab = 5.5 4; and ab = 0. Excused absences require acceptable written documentation to be presented at the class period following the absence. Students are encouraged to call in or email before an absence.

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GRADING

The course objectives and outcomes will be assessed based on the student's level of creativity, teamwork and collaboration, presentations, peer evaluations, blogs, and attendance. The following, Table 3, explains the grading strategy used in the class:

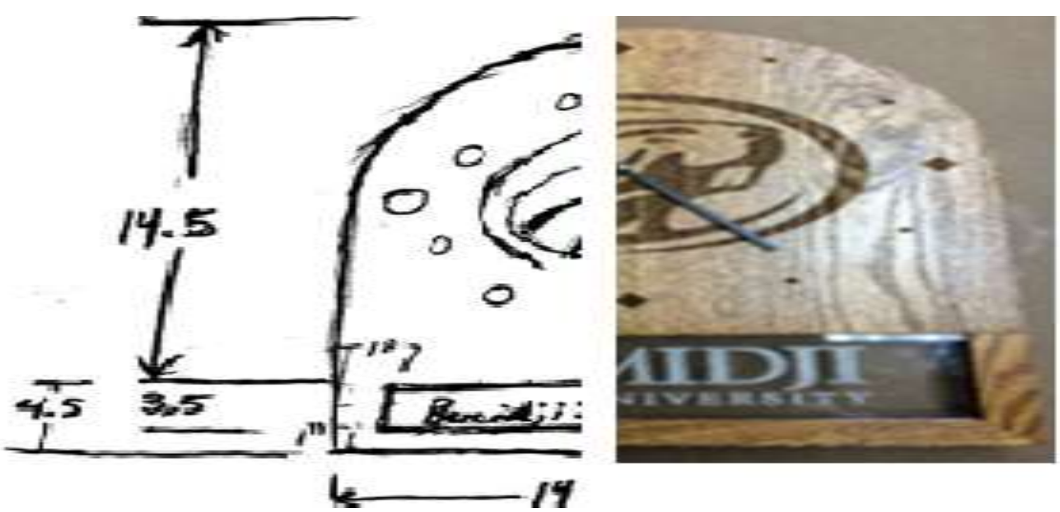
Table 3: grading strategy

Evaluation Category	**Points/ Percent**
Project Proposal & Timeline	20 pts / 20%
Weekly Meetings & Plans	15 pts/ 15%
Collaboration & Manager Evaluation	15 pts/ 15%
Individual Blogs	5 pts/ 5%
Final Presentation& Report	25pts/ 25%
Peer Evaluations	10pts/ 10%
Attendance	10pts/ 10%
Total	**100 Pts/ 100%**

PROJECTS AND BUDGET

The projects in the ERC class are classified into product design and development categories. Students are asked to find a product that they can design, produce, package, and sell. An example is the design and production of a clock with an LED light window, shown in **Figure 3**.

Figure 3: LED clock



CRITERIA FOR SELECTING PROJECTS

Each group is given a budget of $250 to purchase raw material and, especially, tools for their projects. The process for selecting the projects is based on the following criteria:

1- Students should start with market analysis to identify their target market.
2- The Bemidji State University logo should be displayed on the product.

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3- The project should not exceed a budget of $250.
4- Students will work on the project over a 4-month period. It should not be too complicated or too simple.
5- Design and prototype processes should take place within the first two months.
6- The actual production phase will take place after the prototype phase.
7- Products should be made from more than one material.
8- Project should include electrical components (e.g., battery, LED lights, etc.).

TEAM FORMING AND DEVELOPMENT

Developing a multidisciplinary instructor-assigned team is one of the challenges of designing capstone classes. Faculty who are teaching this class have to take enough time to form teams of diverse technical experience based on the courses students have finished or the work experience that they had (e.g., interns). Instructor-selected teams are formed through the best distribution of skills and abilities

Therefore, the resume presentation assignment is important in this class. It gives the instructor an idea on what skills the students have. Some factors and skills that should be considered when forming the teams include GPA, leadership, volunteering background, favorite classes finished, fabricating and manufacturing, electrical, packaging, 2D and 3D design, sales and marketing, and safety.

The most qualified persons are selected as team leaders, and they facilitate a weekly meeting, insure the flow of the process, and adjust plans as needed. The qualifications for the leadership position are calculated using a systematic approach. Scale 1-5 is used, with 5 being the highest. The students with the highest overall average are selected as leaders.

Table 4: factors could be used to select leaders

Factor
GPA factor (1-5)
Leadership factor (1-5)
Volunteer factor (1-5)
Experience factor (1-5)
Other factors (1-5)
Overall

The responsibilities of team leaders are to motivate the team, set weekly meetings with goals, review the goals and time schedules, and report any issue during the work.

Practicing written and oral communication is essential in this class because industry in need of this skill (Todd, Sorensen, & Magleby, 1993). Therefore, several tasks are designed to focus on these skills. One example of a written communication assignment is the daily blog assignment, in which each student is required to write his or her goals for the day. An example of oral communication is prototype phase presentation, in which each team present shows their sample product to the

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other teams. Flow charts, time studies, tools to be used, fixtures and jigs, bills of material, and other details should be included in the presentations.

PRODUCT DESIGN AND DEVELOPMENT APPROACH

There are five phases for designing and developing products in the ERC class.
The first phase is brainstorming. In this phase, students are asked to generate a list of ideas for products, and their functional specifications. Students should consider the market segment on which they want to focus (e.g., students, faculty, gender, children, adult, seniors, etc.). Industry representatives believe that one of the most important aspects of working in a team environment is to value the contributions of teammates who might have different abilities and perspectives from our own. Therefore, a training session on conducting brainstorming is provided so that students become aware of the basic brainstorming rules:

1. No criticism. Any idea is a good idea and it should be listed.
2. Strive for quantity. The more ideas, the better.
3. Combine ideas together and improve them to produce stronger and higher standard projects.

The following points summarize the activities that take place in the first phase:

1. Students research new product ideas or improvements to existing ones.
2. Students identify similar products in the market and the success of such products.
3. Students identify potential customers (required).
4. Students clarify the cost of similarly situated products in the marketplace.
5. Students should work with the resources (e.g., money, machines, time) that are available for them.

The second phase is screening ideas using affinity diagrams and multivoting techniques. Students will be trained to use affinity diagram techniques to organize the ideas generated from the brainstorming session into themes. A multivoing technique is used to prioritize and narrow down the number of ideas that the students have. This technique refers to simply allowing students to vote for the best idea to select their project. Rules should be established on how many votes each student has.

The third phase is developing a product design. In this phase, students are asked to create a hand sketching of their product. Once the sketch is finalized, it will be converted to a digital 2D & 3D technical drawing that shows several views, dimensions, parts specifications, and tolerances. A packaging design is developed in this phase as well.

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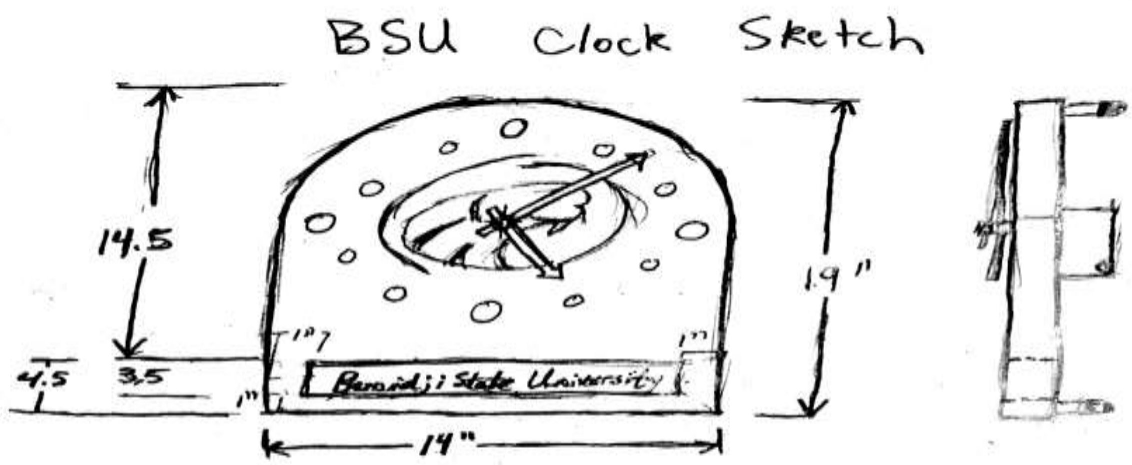

Figure 4: Hand sketch of LED clock

Prototyping, the fourth phase, happens after students get the approval of the instructor and before starting the actual production phase. This phase is important because it will be the first attempt to create a sample of the product. In this phase, teams will deal with hidden problems not considered in the planning phases. As a result, several product modifications will occur in this phase, at the end of which teams will have proven that their products meet the specifications identified in earlier phases. This phase requires students to work in a multidisciplinary team comprising all the types of skills described in the matrix structure in **Figure 2**. Teams will be able to establish an accurate Gantt chart for all the project activities. Process sheets, quality procedures, techniques, tools (e.g., jigs and fixtures) are established in this phase as well. **Figure 6** shows a sample process detail sheet.

Figure 5: LED clock with customized options

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PROCESS DETAIL SHEET

PROCESS ID: 14		PROCESS TITLE: Mount LED Circuit		
TASK SCOPE		SET UP TIME	RUN TIME	TOOLS & EQUIPMENT
TASKS	TASK DESCRIPTION	(PER UNIT)	(PER UNIT)	DESCRIPTION
1	Mount battery sled to back with glue	1	2	Epoxy glue
2	Glue LED strip to bottom of opening	0.5	2	Epoxy Glue
3	Glue acrylic into opening	0.5	2	Epoxy Glue
	Total Setup + (Run Time X 7 Units) =	44		*Time in minutes

Best machine/tool to ensure quality:
Glue is used to hold the LED strip in place along with the provided adhesive strip to ensure a quality bond.

Fixtures needed: none

All resources needed are purchased to save time.

Notes:
*Do all gluing at once as epoxy needs to be mixed

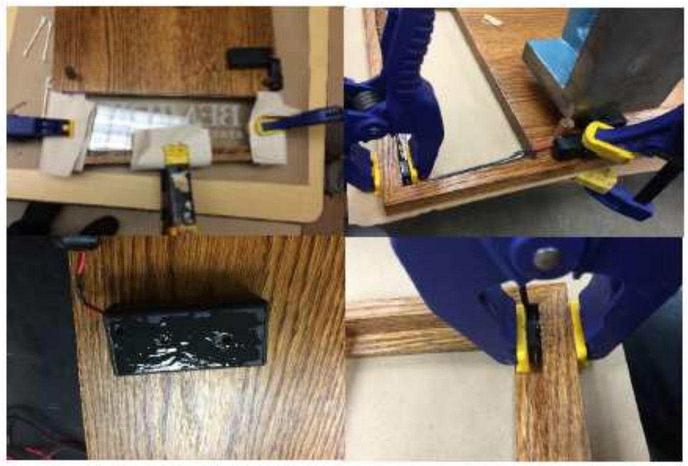

Figure 6: Sample of Process detail sheet

The following activities occur in this phase:

1. Fabricate a quick prototype of the product and the package that meets the proposed functions.
2. Develop jigs and fixtures to ensure the quality of the product and to stay within the allowed tolerances.
3. Produce a sample of the product and the package.
4. Have all team members (i.e., the cross-functional team) review the sample product.
5. Test the sample (e.g., by a drop test).
6. Collect feedback from each member on how to improve the product.
7. Create a sample if major changes have occurred.
8. Establish more accurate tolerances.
9. Based on the testing procedures, adjust and update plans for resources, requirements, procedures, and timelines of finishing the product.
10. Finalize the design drawings and documentations (e.g., parts descriptions, process plans) with reference to all team members.
11. Establish time studies and process details to calculate the team's capacity.
12. Identify the quantity that can be produced based on the capacity and time studies.
13. Develop a production schedule.

14. Finalize the list of potential suppliers.
15. Develop an initial marketing strategy that will be adjusted throughout the process.

The fifth phase is to start production at full capacity. After accepting the product samples, teams can start producing products based on the adjusted plans, tolerances, and instructor feedback. Packages are also prepared in this phase so that products can be made available for customers as orders are received. All products should go through a final quality check before they are sent to the customer.

CONCLUSION

After two years of taking this pilot course, students have found it an excellent experience that helped them to adapt to a real industrial environment. Through this course, students become familiar with solving real world problems, preparing them for professional work and graduate study. After two years of success, the department faculty voted to include this course in the department core and make it required from all technology students. This type of experience provides students with a more realistic picture of the real work environment.

AUTHOR BIOGRAPHIES

Mahmoud Al-Odeh, PhD is an Associate Professor of operations and technology management. He joined Bemidji State University (BSU) College of Business in August 2012. He teaches courses for the B.S. in Engineering Technology, B.S. Project Management, B.A.S Applied Management, and B.A.S Applied Engineering programs. Before joining BSU, he had taught at Indiana State University as PhD candidate in the Applied Engineering and Technology Management department for two years. He also worked in industry as Quality Control Broadcasting Engineer and CAD design engineer. He is a member of IIE, SME, and ATMAE. Dr. Al-Odeh is certified by the Association of Technology, Management, and Applied Engineering (ATMAE) as Certified Senior Technology Manager (CSTM) and Certified Senior Technical Professional (CSTP). He specializes in in the areas of Statistical Quality Control, Value Stream Mapping and Lean Manufacturing, Supply Chain Management Technologies, Radio Frequency Identification (RFID), and Products Development. Dr. Al-Odeh is a reviewer for different journals and conferences. He has been invited to judge several professional events including VEX Robotics competitions, Northern Minnesota Regional Science Fair, and Edison Awards competition. Dr. Al-Odeh has served as a president (2012-2015) of the Distance Learning (DL) division in the Association of Technology, Management, and Applied Engineering (ATMAE).

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