AC 2011-1270: INTEGRATION OF SYSTEMS ENGINEERING TRAINING MODULES INTO CAPSTONE COURSES ACROSS COLLEGE OF ENGINEERING DEPARTMENTS

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PROFESSIONAL PREPARATION 1995 MS Electronics and Computer Control Systems. Wayne State University, Detroit, MI 1990 MBA Business Administration, Michigan State University, East Lansing, MI 1972 BS Electrical Engineering, Michigan State University, East Lansing, MI

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2005 2007 Wayne State University Detroit, MI Part-Time Faculty Taught Project Management in the EMMP and as an elective in the Engineering Master's Program

1973 -2006 Ford Motor Company Dearborn, MI Project Engineering Manager Delivered Electrical Edge/MKX and Fusion/Milan/Zephyr launches with no significant issues. Served as acting Chief l Engineer for Electrical Engineering Large Vehicle Center. Launched Lincoln-Mercury Product Development Electrical Engineering Organization Structure and Interface.

R. Darin Ellis, Wayne State University

Darin Ellis is a faculty member in the Wayne State University Department of Industrial & Systems Engineering, where he teaches and conducts research in the area of human factors engineering. In addition to his human factors research interests, he has been involved in numerous pedagogical research efforts and curriculum improvement projects. In addition to his faculty assignment, Dr. Ellis serves as Associate Dean for Academic Affairs in the College of Engineering. He is a member of the IIE, HFES, INCOSE, and ASEE.

Dr. Walter Bryzik, Mechanical Engineering,Wayne State University

Dr. Bryzik has been serving as DeVlieg Chairman and Professor of Mechanical Engineering , College of Engineering, Wayne State University, Detroit, Michigan from February 2008 to present. He leads the Wayne State University Mechanical Engineering Department from both an educational and research prospective. Dr. Bryzik also personally executes major, state-of-the-art research projects at Wayne State University in areas such as: defense systems engineering and advanced automotive technology, primarily within innovative propulsion systems and alternative fuels areas.

Dr. Bryzik was Chief Scientist of the US Army Tank-Automotive Research, Development, and Engineering Center (TARDEC) in Warren, Michigan, encompassing all Army aspects of ground vehicle technology. He represented the Army worldwide within government, industry, and academia as its chief technical officer in the overall area of DoD ground vehicles. Upon retirement from TARDEC, Dr. Bryzik held the Army/DoD's highest Scientific/Technical rank, a rank which was competitively selected by the Secretary of the Army in recognition of his numerous pioneering technical achievements as an internationally respected leader in the area of advanced ground vehicles. He has authored and co-authored over 200 peer reviewed publications and has contributed to over 20 separate book issues through editing and individual technical paper contributions. He has chaired and/or organized numerous technical international and inter-government conferences responsible for dealing with worldwide advanced automotive technology, and was technical chair of various senior level government committees, particularly with Japan, Germany,

and France. He has served at TARDEC for 40 years in various capacities of increasing responsibility. Dr. Bryzik is a Fellow Grade member of the Society of Automotive Engineers(SAE), an editorial reviewer for SAE, the American Society of Mechanical Engineers, and the Combustion Institute. He has been an Adjunct Professor and Graduate Faculty Member of Mechanical Engineering at Wayne State University for 30 years, both continuously teaching graduate courses and performing advanced research. Dr. Bryzik has served as a member of numerous significant National Academy of Engineering (NAE) panels on advanced automotive technology , and is on the Board of Vistiors wihin the University of Michigan College of Engineering. He was the recipient of the Distinguished Presidential Rank Award in 2004, with the award personally presented by President Bush in Washington DC. This is the highest award given by the US Government for exceptional science and technology and its impact on society, Dr. Bryzik received a bachelors (highest honors), masters, and doctorate in mechanical engineering from the University of Detroit.

Dr. Kyoung-Yun Kim, Wayne State University
Dr. Ming- Chia D Lai, Wayne State University

Dr. Ming-Chia Lai received his BSME from National Taiwan University (1975), MS and PhD from Pennsylvania State University(1985). He also carried out post0doctoral research at Gas Dynamics Lab. at University of Michigan (1985) and Energy Lab of Massachusetts Institute of Technology (1986). He has a faculty of Wayne State University since 1987. Prof. Ming-Chia Lai's research has been on the thermal-fluid engineering, automotive powertrain, and alternative energy applications. His research has been sponsored by both government agencies (DOE, DOD, NASA, NSF, NIST) and industry (GM, Ford, Chrysler, General Dynamics, Detroit Diesel, John Deere, Delphi, Visteon, Eaton, Continental, Bosch, Hyundai, Honda, TIAX, DuPont, and Ferrari). He has authored or co-authored more than 300 refereed journal and conference publications. His awards include Charles DeVlieg Distinguished Endowed Professorship, WSU Career Development Chair Award, ASME Young Engineer of the Year, SE Michigan, American Natural Resources Research Award, WSU Faculty Research Award, and The Best Paper Award, 23rd Nat'l Heat Transfer Conference (ASME and AIChE), SAE Forest R. McFarland Award and SAE Fellow.

He is also active in student capstone design and national student competition projects, including Ethanol Challenge, Hydrogen Student Design, SAE Formula Car, and DOD System Engineering Capstone Design. In addition to Mechanical Engineering, he is also a faculty of the the interdisciplinary Alternative Energy Technology (AET), and the Electric-Drive Vehicle Engineering (EVE) Degree programs.

Dr. Yun Seon Kim, Wayne State University

Title: Integration of Systems Engineering Training Modules into Capstone Courses across College of Engineering Departments

Background:

The Department of Defense (DoD) has identified the promotion of Systems Engineering (SE) knowledge and career path awareness for undergraduate engineering students as a key strategic initiative (1). The DoD chose exposing engineering students to systems engineering training in capstone projects because they are required for all ABET-certified colleges of engineering in the United States (2).

Wayne State University decided on a novel approach to achieving this objective by introducing SE training modules into existing capstone courses across both the Industrial and Systems Engineering and Mechanical Engineering departments starting in the Fall Semester, 2010 (3). Instructors of the courses collaborated to approach a DoD-relevant design problem, i.e. development of humanitarian assistance/disaster relief kit elements, from multiple perspectives. These modules were developed by one instructor and either taught in joint class sessions or in individual classes where scheduling conflicts could not be overcome. Beyond the Department of Defense objectives, these training modules are being used as a method of achieving continuous improvement in the capstone courses. The first module is an introduction to systems engineering while other modules relate to systems engineering tools that are taught 'just-in-time' to support completion of the capstone design projects.

Implementation Method:

The SE training modules were developed by an Industrial and Systems Engineering faculty member under the consultation of the Assistant Director of Wayne State University's Office of Teaching and Learning.

The process began with the development of an instructional design matrix which included: Instructional Goal, Objectives, Assessment Methodology, Information Presentation, Practice and Feedback, and the Media and Materials to be used (4). An example of an Instructional Goal was: "Students will be able to define and describe systems engineering." An example of an Objective was: "Define the term 'system' in the context of systems engineering. Assessments included pre and post-tests based on DoD overall strategic objectives. The pre-test was conducted prior to the students receiving any SE instructional material to assess their base competency. The post-test was conducted at the end of the semester to assess how much SE knowledge was gained after SE instructional material was delivered and used on course projects. Information Presentation was via lectures. Practice and Feedback included interactive in-class discussion, development of in-class examples, and incorporation of tools in capstone or term projects. Media and Materials included PowerPoint presentations, examples, and templates for students to use in their projects.

The modules were inserted into three courses in the Mechanical Engineering and Industrial and Systems Engineering programs at the undergraduate and graduate level (9 teams, with a total of over 30 students). All courses used humanitarian assistance/disaster relief kits as the target domain. Students successfully used System Engineering tools in all courses and pre-/post-course assessment indicate an increased awareness of and interest in Systems Engineering.

Assessment Plan:

Each of the participating courses was examined and selected based on relevance to the targeted SE concepts and competencies. Each learning objective was associated with at least one assessment. Assessments instruments varied by course and by outcome. In addition to course-specific assessments, three common assessments were administered for all courses: 1) SE Career Awareness / Interest Survey, 2) Assessment to Measure Students' ability to transfer SE Learning to Novel Problems, and 3) Open-Ended Blog Postings by students that documented and reflected on capstone progress.

Course Evaluation / Improvement Plan:

Four Fall Semester 2010 courses implemented some System Engineering elements.

The primary contribution of the Systems Engineering class was to prepare and deliver lecture modules for all of the participating classes. The following modules were delivered:

- Introduction to Systems Engineering
- Pugh (concept alternative selection) Analysis
- Failure Mode and Effect (risk identification and mitigation) Analysis (FMEA)

The faculty member also provided assistance in developing the FMEA and using it to improve that design for one of the Mechanical Engineering senior capstone teams. This assistance was provided by meeting with the team several times, guiding their work, assisting them in following the FMEA process, and brainstorming several engineering changes that would improve the design.

One of the Mechanical Engineering senior capstone courses implemented (**T**eoriya **R**esheniya **I**zobretatelskikh **Z**adatch) TRIZ. The TRIZ principles were emphasized in the design process, such as the notion of "Ideal System" as well as generic techniques for resolving contradictions. Pugh Analysis was also used to identify the best alternative which was progressed to a physical prototype.

The other Mechanical Engineering courses implemented TRIZ, Pugh Analysis, and FMEA. A DoD mentor, serving as a content expert and as part of the external reviewer panel during final project presentations, supported the senior capstone projects via e-mail and Skype. The mentor also provided final report as well as presentation feedback. Mentor feedback provided both encouragement and confirmation of students' efforts during the course of the semester. Students also had access to two industry experts; one a laboratory head and the other a Chief Technologist. One expert was enlisted via an e-mail request; the other via a long-term research collaboration. These experts provided comments and suggestions on reports and also

served as external reviewers during project presentations and a follow-on oral examination portion of the senior capstone project. Expert feedback also provided both encouragement and confirmation of students' efforts during the course of the semester. Faculty reported that the mentors and experts complemented the learning and design processes of the student teams. The System Engineering tools improved project outcomes and are planned for future use as part of the continuous improvement plan.

The fourth class was an integrated product development course. The aim of this class was to familiarize students with the current principles and philosophies of product development and realization. This class educated students about the importance of integrated and collaborative product development in a global economy and how to realize a true integrated and seamless development environment. Via the product realization projects, students learned how to operate effectively in a highly integrated, multidisciplinary environment. In the fall semester, 2010, project teams were formed on the base of student expertise and experience. Teams consisted of three or four students. The project team's goal was to develop humanitarian assistance/disaster relief (HA/DR) materiel with the benefits of alternative and renewable energy technologies. The developed SE course modules were applied; Tradeoff Analysis, TRIZ, Analytic Hierarchy Process, QFD, Requirement Engineering, and Introduction of SE. Students were assessed based on the following topics;1) use of the product development standard process and procedures to set final specifications based on customer needs, and 2) generating innovative design concepts for all components and sub-assemblies comprising a product. The anticipated product design conformed to standard criteria for high-quality industrial designs for manufacturing and assembly as well as a production launch plan with complete documentation for each production process. In this fall, four student teams worked on the development of 1) solar medical facility; 2) manual power generator; 3) mobile sanitation station; and 4) wind current kite. This class utilized the newly developed Systems Engineering - Student Query, Interview, and Response Tool (SE-SQUIRT) to obtain students' Pre-test, Surveys, Weekly reports and Post-test.

For the winter 2011 semester, more communication with HA/DR experts has been requested because students do not have the experience to understand HA/DR projects. The experts can provide reasonable and appropriate information to achieve the goal of these projects. They may also be able to provide real world experience regarding these products.

Plans are currently being developed to use lecture capture methodology so that these modules can be more easily inserted into existing courses. Plans are also being made to develop more modules for other SE tools and to expand this instructional approach across other departments in the College of Engineering.

Pre / post-Test Results:

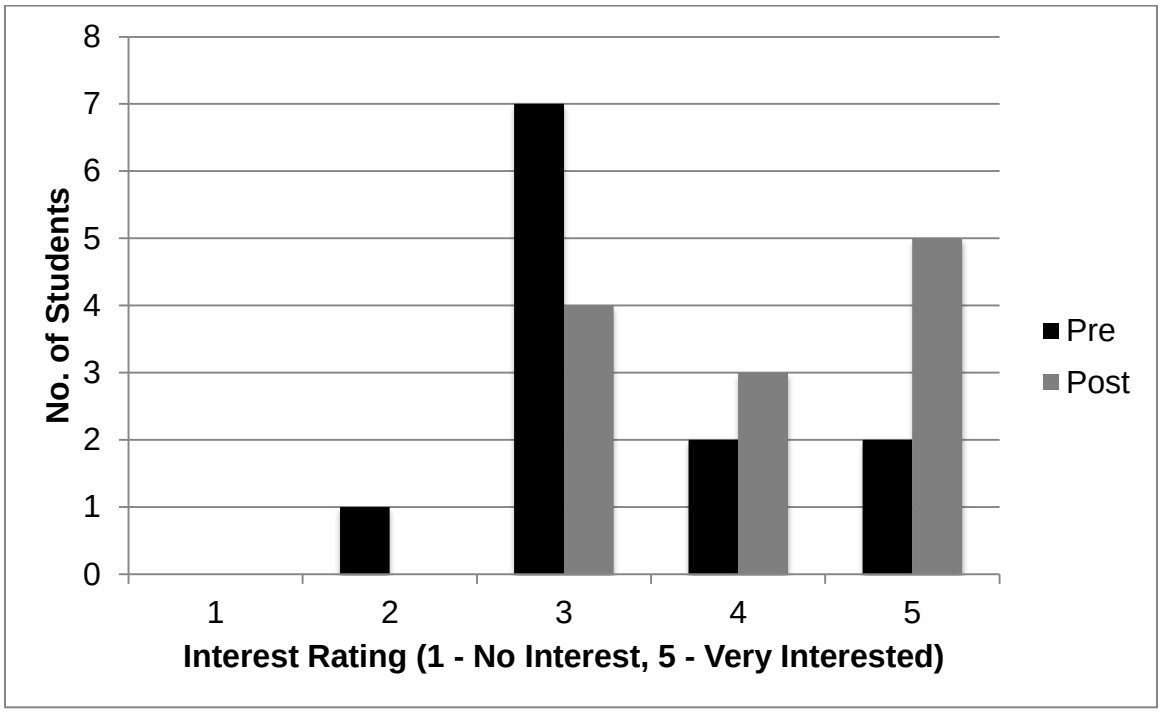

Figure 1. Histogram of interest ratings pre- and post-class experience.

The SE background gained in this class from both the lecture material and application of tools led to an increased interest in SE careers. As seen in Figure 1, when asked "how interested are you in becoming a systems engineer?" a sub-sample of 12 students who completed both the pre- and post-class assessments declared a higher level of interest after their class experience – the entire distribution of responses shifted to the right, increasing the number of very interested students, and eliminating the negative response side of the distribution. In addition, the number of neutral or not sure answers was reduced, all in a positive direction. The mean within-student rating change was +0.67 and a one-tailed paired T-test showed this was a statistically significant improvement ($p=0.0064$).

Conclusions:

This novel approach to achieving the Department of Defense objective of promotion of Systems Engineering (SE) knowledge and career path awareness for undergraduate engineering students by exposing engineering students to systems engineering training in capstone projects because they are required for all ABET-certified colleges of engineering in the United States has achieved measurable success.

Because this methodology also improved Senior Capstone Project outcomes as reported both by Department of Defense mentors and faculty, the plan is to continue this methodology within the Mechanical and Industrial and Systems Engineering departments. It is also

expected that this methodology will be expanded to include other SE tools modules and will be propagated across other College of Engineering departments.

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