122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12374

# Vertical Integration of Capstone Projects in Multiple Courses in the Engineering Technology Programs

**Dr. Morteza Sadat-Hossieny, Northern Kentucky University**

MORTEZA SADAT-HOSSIENY is currently associate professor and director of Engineering Technology programs at Northern Kentucky University. Dr. Sadat received his B.S.in Manufacturing Engineering Technology from Oklahoma State University, M.S. Manufacturing Eng. Tech from Murray State University and Ph.D. Industrial Technology, Iowa State University. His areas of concentration are CAD, Industrial Automation, Alternative Power Generation Methods and his research Interests are Globalized Engineering/Technology Education, EGT innovative curriculum development.

**Dr. Mauricio Torres, Northern Kentucky University**

Dr. Torres received a B.S. in Business Administration from City University of Sao Caetano do Sul, B.S. in Mechanical Industrial Engineering from Braz Cubas University, Brazil, M.S. in Engineering Management and Ph.D. in Industrial and Systems Engineering from Florida International University. He has over 30 years of experience in heavy machinery manufacturing industry and currently he holds the position of Assistant Professor in the Mechanical Manufacturing Engineering Technology Program at Northern Kentucky University. His research interests are manufacturing processes, enterprise engineering and engineering education.

# Vertical Integration of Capstone Projects in Multiple Courses in the Engineering Technology Programs

The Senior Project at NKU

In Engineering Technology Programs the objective of capstone projects is two-fold: provide an opportunity to evaluate the use by students of the knowledge acquired during the program and to facilitate the program assessment process by addressing the attainment of the "Student Learning Outcomes", as defined by ABET [1].
The project assignment is a task based on questions and problems involving students in design, problem solving, investigation and decision making, under the leaning model referred to as Project-Based Learning (PBL) [2]. The project gives the students the opportunity to work relatively autonomously over extended periods of time and they culminate in realistic products or presentations [3]. The written report submitted by students must include the outcomes of their experiences in approaching and addressing the different engineering challenges that have arisen from the design and execution. Students are also expected to present the product resulting from the project execution.

Challenges posed to students by the Senior Projects Requirement

Brooks et al. [4] has pointed out two perspectives to any assessment of a curriculum in higher education: the first considers the aim of the curriculum and the connections we intend to make between knowledge and life; the second perspective examines how that aim is accomplished. An increased focus on the second perspective (student outcomes) has generated a discussion about what an appropriate outcome measure should be [5] and PBL is a powerful measurement tool. Employing the PBL in schools, however, is not an easy task for several reasons, as has been noticed by Marx et al. [6]: projects often take longer than anticipated; it is hard to let students to work on their own, on the one hand, while maintaining control of the class, on the other; and there is the question of how to integrate the project method into a system that is based generally on formal evaluation and exams. Ideally students should start thinking about their capstone projects when they reach the junior academic status, e.g., when they have enough technical and academic maturity to select a subject that fits best with their own interests and the program requirements. Submitted projects however have shown that decisions on capstone projects are taken in a later stage of the program, more specifically, mostly during the very same semester when the projects are due. This poses a challenge in selecting a subject that really provides the necessary elements for a thorough assessment of the students learning outcomes.
Some initiatives have been implemented to address those issues, such as the senior project programs in cooperation with local industries (e.g. NKU/Mazak Corp. Joint Senior Project Program [7]) and other experiential learning opportunities. These initiatives however, are not available to all students and/or don't necessarily guarantee a proper learning outcomes assessment, as they may not be specifically tailored to this purpose.

## The Vertical Integration

In response to requirements and advice from industry and other stakeholders with respect to the desired knowledge, skills, and abilities of future graduates [8], NKU Engineering Technology curriculum design has been directed towards a more attentive approach in valuing knowledge integration, increasing students' responsibility on the learning process and adding industry-integrated extra-class activities [9]. The assessment of the program outcomes through the Senior Project still needs to be addressed. Also, from the educational point of view, curricular integration has been a serious recurring recommendation [10].

In this paper we propose a vertical integration of projects in different courses in order to improve the evaluation of the students' knowledge of the subject matter, as well as help facilitate the ABET assessment process [1]. A design and execution of a relatively complex product which requires knowledge in different levels of technical proficiency will be proposed in an earlier stage in the program. Students will be required to address the various technical challenges as they progress towards more advanced classes. This process will provide an opportunity to evaluate students' level of knowledge in a planned and incremental procedure, culminating in a more accurate assessment of their learning outcomes.

We will continue to use the existing program capstone course EGT417 (Senior Project in Engineering Technology), as the class where the students will conclude and present their senior projects as the culminating effort towards graduation. This course is described in the NKU Undergraduate Catalog as the "Preparation and proposal for the capstone project design in an area of student's primary program major. After the preparation and proposal is prepared, with permission from their advisors, students design, build, document, demonstrate, and present the results. Must be taken within three semesters of graduation, may be repeated up to 9 semester hours" [11]. The objectives of this course will remain unchanged.

## NKU Mechanical Manufacturing Engineering Technology (MMET) program Structure

This program provides students with both the technological and managerial skills necessary to enter careers in design, application, installation, manufacturing, operation, and maintenance of mechanical systems. Graduates gain skills to analyze, design, apply, and troubleshoot systems with electronic, digital, analog, microcontroller, software, and mechanical components. The combination of practical and theoretical education leads to graduates with diverse technical skills throughout a wide range of applications. Students are required to co-op in industry starting with their second year at school, which often continues and leads to full-time employment [11].

Our curriculum is incremental learning based, where the MMET knowledge, skills and competencies are built progressively and tasks are expected to be carried out by the students satisfactorily [12]. The list of courses required in the program is depicted in table1 and the sequence by which the courses should be taken is depicted in figure 1.

| | | |
|---|---|---|
| **Support Requirements** (29 credits) | | |
| CHE 120 & 120L | General Chemistry | (4) |
| EGT 267 | Programming for Engineering Applications | (3) |
| MAT 119 | Pre-Calculus | (3) |
| MAT 128 | Calculus 1A OR take MAT129 in place of | (3) |
| MAT 227 | Calculus 1B MAT128 & 227 | (3) |
| PHY 211 | General Physics with Lab I | (5) |
| PHY 213 | General Physics with Lab II | (5) |
| STA 205 | Introduction to Statistical Methods | (3) |
| **Core Requirements:** (57 credits) | | |
| EGT 116 | Intro. to Industrial Materials & Processes | (3) |
| EGT 161 | Industrial Electricity & Electronics | (3) |
| EGT 211 | Quality Control | (3) |
| EGT 212 | Computer Aided Drafting & Design | (3) |
| EGT 261 | Engineering Materials | (3) |
| EGT 265 | Manufacturing Processes and Metrology | (3) |
| EGT 300 | Statics & Strength of Material | (3) |
| EGT 301 | Cooperative Education in Eng. Technology | (3) |
| EGT 310 | Project Management & Problem Solving | (3) |
| EGT 318 | Introduction to Nano-Technology | (3) |
| EGT 320 | Robotic Systems & Material Handling | (3) |
| EGT 340 | Applied Dynamics | (3) |
| EGT 361 | Fluid Power | (3) |
| EGT 365 | CNC & Manufacturing Process Planning | (3) |
| EGT 380 | Machine Design | (3) |
| EGT 417 | Senior Research & Design in Eng. Technology | (3) |
| EGT 405 | Metrology and Geometric Tolerancing | (3) |
| EGT 450 | Thermodynamics & Heat Transfer | (3) |
| EGT 465 | Automated Manufacturing Systems | (3) |
| **Optional Courses (two courses listed below):** 6 credits | | |
| EGT 260 | Industrial Standards, Safety and Codes | (3) |
| EGT 280 | Intro to Microtechnology | (3) |
| EGT 362 | Tool Design and Computer Aided Mfg. | (3) |
| EGT 386 | Electro-Mech. Instrumentation & Control | (3) |
| EGT 411 | Quality Assurance and Auditing | (3) |
| EGT 423 | Planning & Design of Industrial Facilities | (3) |
| **Emphasis in DESIGN** (6 credits) | | |
| EGT 412 | Advanced CADD | (3) |
| EGT 462 | Applied Finite Element Modeling | (3) |
| **Emphasis in QUALITY** (6 credits) | | |
| EGT 321 | Productivity Management, Scheduling, & Planning | (3) |
| EGT 341 | Integrated Resource Management | (3) |

Table 1 – MMET required courses

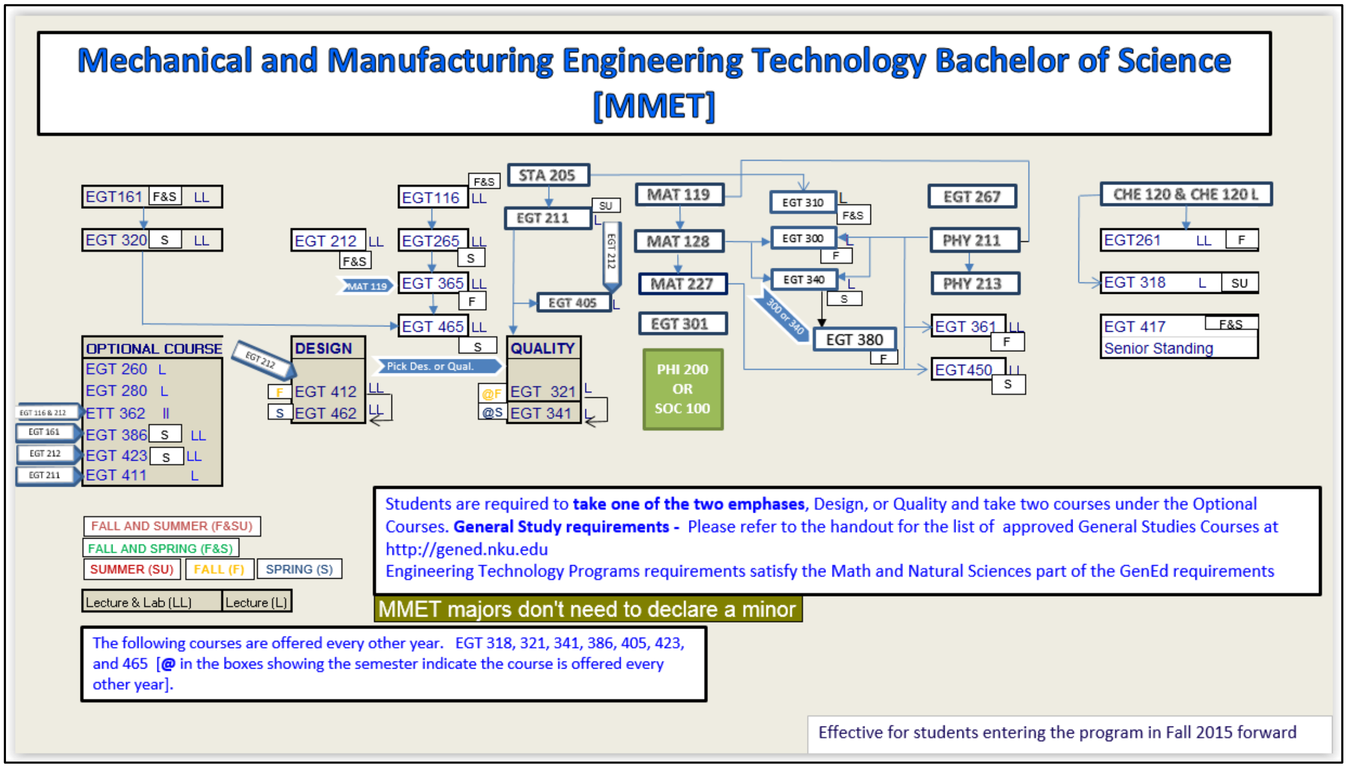


Figure 1 – MMET course sequence and pre-requisites.

Senior Project Development Approach

The lack of a complete understanding of how to develop a design (product, process, system, etc.), also poses an additional challenge to students in carrying out their senior project assignments. Observations made during past semesters revealed that most students have a good comprehension of mechanical systems, as well as satisfactory technical knowledge and ability to approach a problem solution appropriately; however most of them fail to harness their ideas into a functional design. Among the measures considered to improve the senior project experience is the development of a new 300 level course (EGT3XX) about product development and design. This new product development and design course will be a core requirement for all students and a prerequisite for the senior project class EGT417.
For the purpose of this paper we will assume the development of projects should follow a structured flow using the functional decomposition technique described by Ulrich and Eppinger [13]. The identification of the appropriate classes on our program, where the different levels of the development will be conducted as the student progresses through the program as depicted in figure 2.

Although the emphasis for senior projects is on design type projects, according to Ulrich and Eppinger [13] the six phases of generic product development process is similar in a Marketing, Design, Manufacturing, or other type of product development process. Therefore, other projects like optimization and/or improvement of manufacturing processes may follow the same approach.

If a student decides on a Project at the sophomore year and changes his or her mind later, the question that might arise is “how is this problem going to be handled?” The answer to this question is, since the student has followed the product development process during the curriculum, he/she has acquired the competencies to formulate a successful project and should be in a better position to plan and execute his/her new senior project in a shorter amount of time.

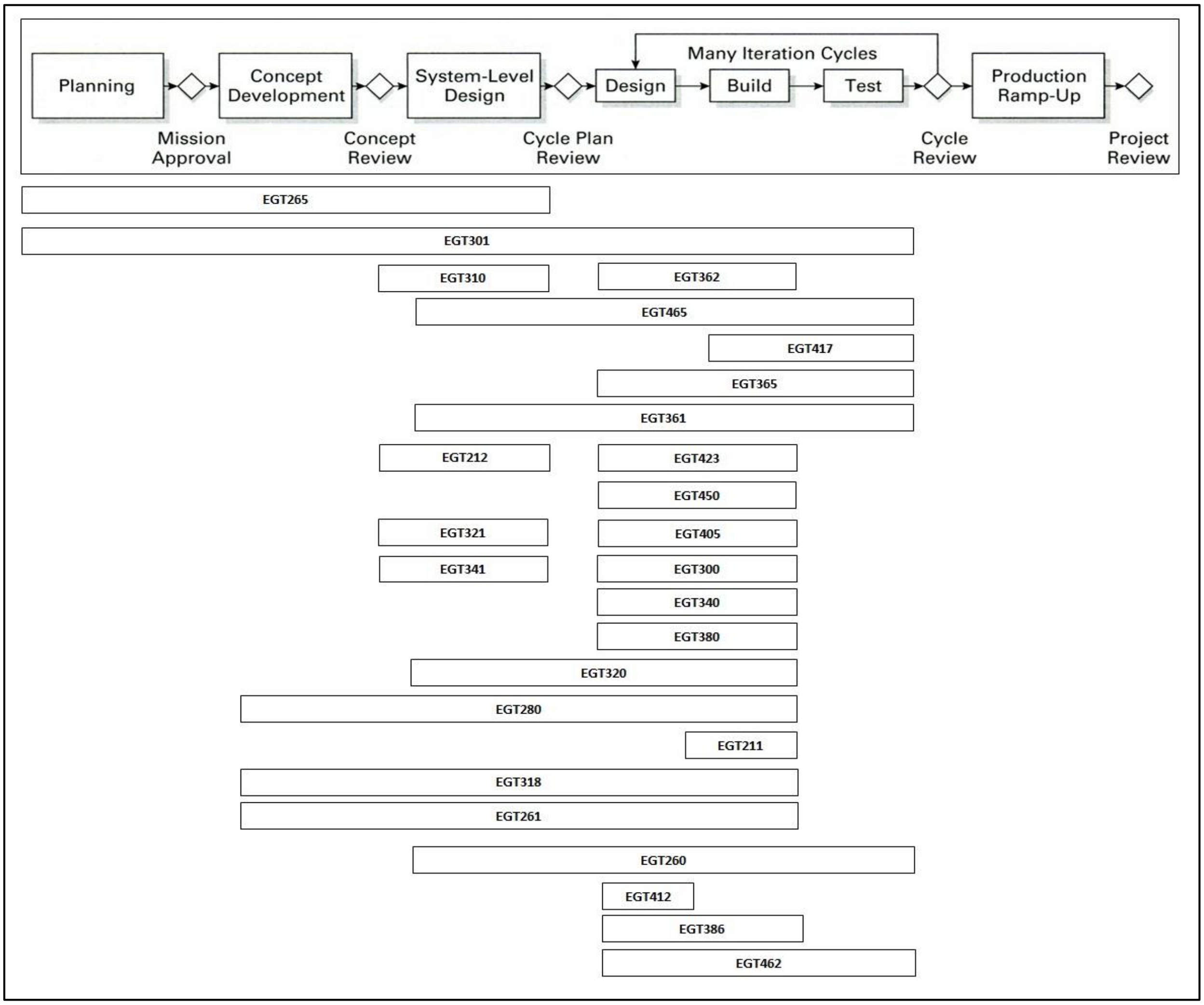


Figure 2 – Spiral Product Development Process- Flow Diagram

The "Four Pillars of Manufacturing Knowledge" as the Framework for the Vertical Integration.

The Four Pillars of Manufacturing Knowledge [14] is a model which provides a basic vision on the knowledge required by manufacturing professionals, in order to assist the ABET accreditation process for manufacturing engineering related programs. It was developed from previous work done by the Society of Manufacturing Engineers (SME) [15]. Figure 3 depicts how the MMET program is aligned to the SME's "Four Pillars of Manufacturing Knowledge"; each of the Four Pillars is a particular major aspect of the manufacturing engineering field [16]. As the model is intended to provide guidance to educators in curriculum design and continuous improvement, we believe it provides a natural framework for the vertical integration of the senior projects. The Spiral Product Development Process as seen in figure 3 provides the basis on which the vertical integration will be set in the Four Pillars framework.

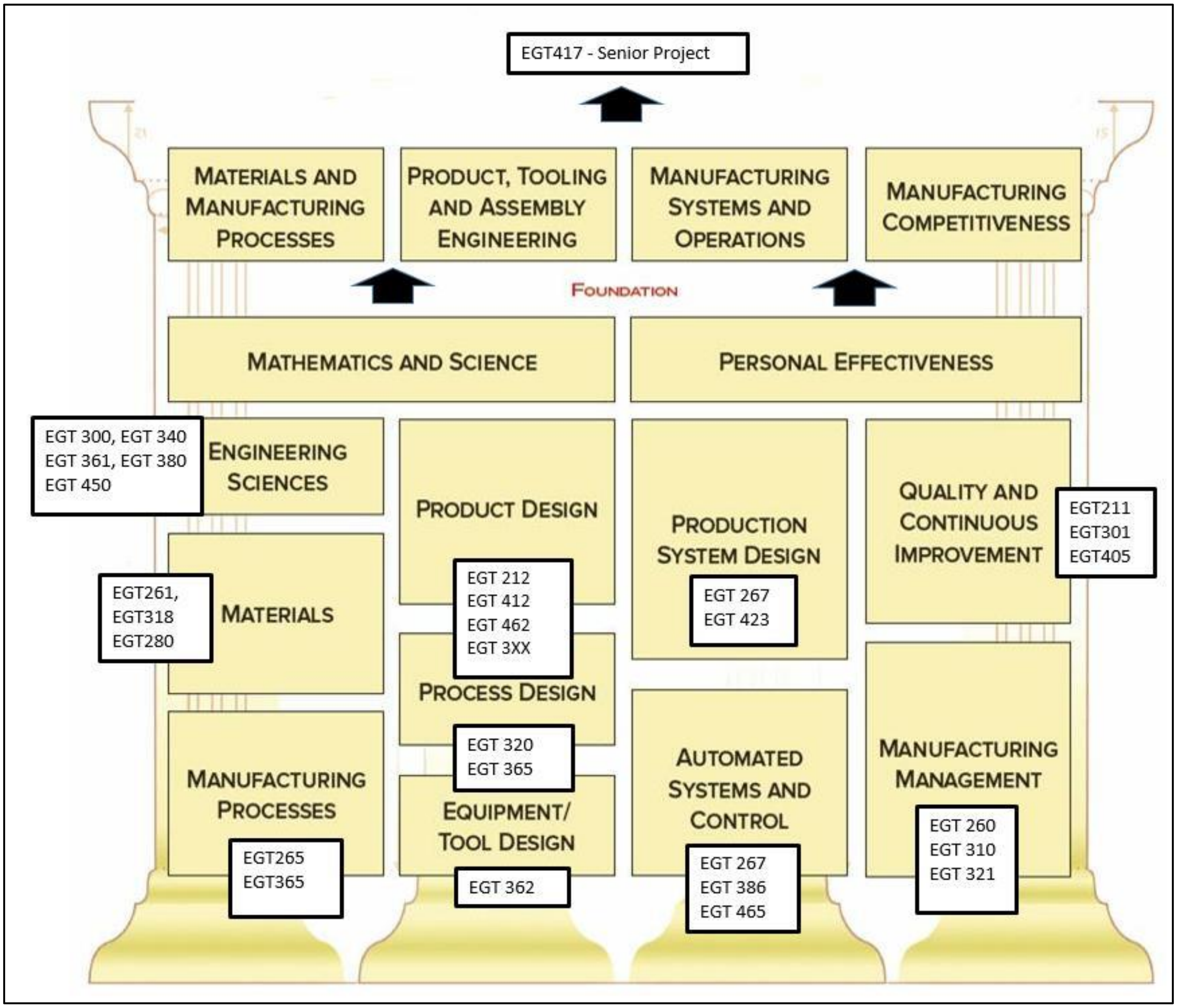


Figure 3 – EGT Courses within the Four Pillars of Manufacturing Knowledge.

Implementation with the Participation of Local Employers

Our current partner in the Joint Senior Project Program (NKU/Mazak Corp. Joint Senior Project Program) [7]), has suggested to start the students' involvement with the senior projects by offering co-op opportunities, where part of the development will be carried out. The tasks will be related to engineering problems, for which solutions will be sought and implemented. We emphasize the resources available to students and the hands on experience provided to the students at the Mazak facility cannot be emulated in an educational setting like NKU. This real work manufacturing experience is hard to emulate even with the capital cost expenditure made by schools in order to maintain laboratories that reproduce a modern industrial facility [7]. Students majoring MMET are mandated to take EGT 301 (Co-op) class at any point during the program once after the first semester. However, this course can be repeated many times, if offered by the co-op employer.

Instructors will play a fundamental role in this initiative, providing students with essential technical advice in their respective courses. Instructors that agree to participate in the initiative may assign tasks/assignments that would be related to their proposed senior projects and use them for class grading, thus creating an additional opportunity to motivate students.
Top performing students enrolled in the class EGT265 (Manufacturing Processes and Metrology) will be selected to do co-op as they go through the program. The starting point of this new initiative will be EGT 265, as we believe at that point those students will have an adequate technical and academic maturity necessary to succeed in working in industry and pursue their studies in a more organized fashion. They can think ahead and propose senior projects that upon approval, they can work on as part of the classes they take toward their major. It is also assumed that the academic plan agreed between the students and advisors will be adhered to with few deviations.
We would follow the guidelines specified by NCEES [17] to screen the projects proposed by students participating in this experience. A partial list of competencies that are useful in guiding, mentoring, and verifying progressive engineering experiences are:

Practical application of theory:

- Analysis, Design, Testing, Implementation, Systems Applications, Time in the Engineering Process, Experience and Understanding of the project.

Important management topics would involve:

- Planning, Scheduling, Budgeting, supervising and human resource management, project completion plans

On the communication skills these projects have to involve courses that:

- Accumulate project knowledge
- Transmit project knowledge

For social implications – important concepts are those that:

- Promote and safeguard the health and safety as well as the welfare of the public;
- Demonstrate an awareness of the consequences any negative impact;
- Follows a code of ethics that promotes integrity and engineering professionalism.

Students that adhere to this process are expected to work on different aspects of their senior projects as they take classes that deal with the above concepts in a gradual but interactive format [18].

## Conclusion

The senior project course EGT417 outcomes are mapped according to the ABET accreditation criteria [1], as depicted in table 2. Similarly all other MMET program courses are also mapped, each one with its own set of outcomes to be met.

| **Map of Course Competencies with Student Outcomes**<br>(1 - Direct & Strong Link, 2 - Indirect Support) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Course** / **MMET Outcomes** | **SO1** | **SO2** | **SO3** | **SO4** | **SO5** | **SO6** | **SO7** | **SO8** | **SO9** | **SO10** | **SO11** |
| EGT417 - Senior Research & Design in Eng. Technology | 1 | | | 1 | | 1 | 1 | 1 | 2 | | 1 |

| ABET CRITERION 2 (PROGRAM OUTCOMES) |
|---|
| **SO1. [a]**: An ability to select and apply the knowledge, techniques, skills, and modern tools of mechanical and manufacturing engineering technology to the design, manufacturing, testing, evaluation, and maintenance of mechanical and manufacturing systems; |
| **SO2. [b]:** An ability to select and apply a knowledge of mathematics, science, engineering, and technology to selection of materials, manufacturing processes, tooling, automation, production operations, maintenance, quality, industrial organization, management and statistics to solve mechanical and manufacturing problems; |
| **SO3. [c]:** An ability to conduct standard tests and measurements of engineering materials, statics, dynamics, fluid power, and electronics; |
| **SO4. [d]:** An ability to: |
| I. design systems, components, or processes and apply to mechanical and manufacturing projects; |
| II. produce drawings and related electronic data files and apply to the areas of mechanical design, tool design and machine design; |
| **SO5. [e]:** An ability to function effectively as a member or leader on a technical team; |
| **SO6. [f]:** An ability to identify, analyze, and solve engineering technology problems in; |
| I. mechanical and manufacturing processes, planning, optimization and automation; |
| II. facilities planning, materials handling and robotics; |
| **SO7. [g]:** An ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature; |
| **SO8. [h]:** An understanding of the need for and an ability to engage in self-directed continuing professional development; |
| **SO9. [i]:** An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity; |
| **SO10. [j]:** A knowledge of the impact of engineering technology solutions in a societal and global context; and |
| **SO11. [k]:** A commitment to quality, timeliness, and continuous improvement. |

Table 2 – Table of Course EGT417 Competencies to Students Learning Outcomes

Compared with the conventional senior projects, vertically integrated course projects in the curriculum would be beneficial in multiple ways, including:

1) Learning Outcomes listed above under EGT 417 could be assessed in multiple courses as students' progress through the curriculum and gain fundamental knowledge. Students show how well they understand the concepts by applying concepts learned and complete parts of their senior projects in each class;
2) Vertically integrating senior projects would also help reduce students' anxiety toward a comprehensive senior project. It might help improve student retention rate and increase the number of graduated in the program.

3) As mentioned above, the vertical integration of capstone projects in multiple courses will guide the students through a multidisciplinary path, carrying out a task to be performed progressively along the academic program with the addition of industrial experience opportunities.

The vertical integration will be implemented as our industry partners make co-op opportunities available to our sophomore students; Mazak Corporation already presented to our students opportunities to an early start in senior projects through co-op, adjusting the format of existing joint senior project program [7]. The vertical integration is being implemented and its effectiveness will be evaluated when current sophomore students who are currently engaged in their senior projects finished the EGT417 class, within four to six semesters.

Capstone projects are an important component of the learning process, as well as of the assessment of the students and the academic programs. The format currently offered to students does not assure the appropriate assessment of the learning outcomes, demonstrating the need for a reformulated senior project approach. Also, choosing the Four Pillars of Manufacturing Knowledge as a framework will allow a more meaningful assessment for ETAC-ABET accreditation.

## References


[1] ETAC, *2013-2014 Criteria for Accrediting Engineering Technology Programs,* ABET (Accreditation Board for Engineering and Technology), 2012.

[2] J. W. Thomas, "A review of Research on Project-Based Learning," 2000. [Online]. Available: http://www.bie.org/research/study/review_of_project_based_learning_2000.

[3] M. Barak and A. Shachar, "Projects in Technology Education and Fostering Learning: The Potential and Its Realization," *Journal of Science Education and Technology,* vol. 17, no. 3, pp. 285-296, 2008.

[4] R. Brooks, J. Benton-Kupper and D. Slayton, "Curricular Aims: Assessement of a University Capstone Course.," *The Journal of General Education,* vol. 53, no. 3/4, pp. 275-287, 2004.

[5] T. Bailey, J. C. Calcagno, D. Jenkins, T. Leinbach and G. Kienzl, "Is Student-Right-to-Know All You Should Know? An Analysis of Community College Graduation Rates," *Research in Higher Education,* pp. 491-519, 2006.

[6] R. W. Marx, P. C. Blumenfeld, J. S. Krajcik and E. Soloway, "Enacting Project-Based Science," *The Elementary School Journal,* vol. 97, no. 4, pp. 341-358, 1997.

[7] M. Sadat-Hossieny and M. Torres, "NKU-Mazak Corp. Joint Senior Project Program," in *21st ASEE Annual Conference*, Indianapolis, 2014.

[8] NKIP Advisory Committe for Continuing Education, "Industry Partnership Survey - Northern Kentucky," Burlington, KY, 2013.

[9] M. Torres and M. Sadat-Hossieny, "Modifying the Curriculum of an Engineering Technology Program to meet the Needs of Local Manufacturing Consortium.," in *2014 IAJC/ISAM Joint International Conference*, Orlando FL, 2014.

[10] R. Case, "The Anatomy of Curricular Integration," *Canadian Journal of Education / Revue canadienne de l'éducation,* vol. 16, no. 2, pp. 215-224, 1991.

[11] NKU, "Undergraduate Catalog - Engineering Technology Majors," [Online]. Available: http://nkuonline.nku.edu/smartcatalog/engineering-technology-majors.htm.

[12] C. Nygaard, T. Hojtl and M. Hermansen, "Learning-based Curriculum Development," *Higher Education,* vol. 55, no. 1, pp. 33-50, 2008.

[13] K. T. Ulrich and S. D. Eppinger, Product Design and Development, 5th. ed., New York: McGraw-Hill, 2012.

[14] R. J. Bennett, N. Latif, A. Sikoski, S. Wendel and M. A. Zahraee, "LEADERSHIP for Manufacturing and Manufacturing-related Programs," in *21st ASEE Annual Conference*, Indianapolis, 2014.

[15] SME, "Four Pillars of manufacturing Knowledge," [Online]. Available: http://www.sme.org/uploadedFiles/Membership/Technical_Communities/Manufacturing_Education_and_Research/Four%20Pillars%20Flyer.pdf.

[16] R. Mott, H. Jack, V. Raju and M. Stratton, "The Four Pillars of Manufacturing Engineeing," in *Proceedings of the 2011 SME Annual Meeting,*, Bellevue WA, 2011.

[17] "NCEES Advancing Licensure for Engineers and Surveyors," National Council of Examiners for Engineering and Surveying, [Online]. Available: http://ncees.org/.

[18] "Suggested Guidelines for Progressive Engineering Experience," Minnesota Board of Architecture, Engineering, Land Surveying, [Online]. Available: http://mn.gov/aelslag/progexpeng.pdf.