Integrated Professional Component Plan from Freshmen Experience to Senior Project

Chris Byrne, Robert Choate, Joel Lenoir and Kevin Schmaltz
Western Kentucky University

Abstract

The Mechanical Engineering (ME) faculty at Western Kentucky University (WKU) have developed and implemented a Professional Plan to assure that graduates of the program will have experienced key areas of the engineering profession and demonstrated their abilities to perform in a professional manner. This Professional Component has been divided into Engineering Design, Professional Communications, Computer Skills Tools, and Engineering Ethics, with students receiving instruction and practice in each area at least once per academic year.

Engineering Design experiences combine a structured approach to solving problems with an appreciation for the art of engineering. Professional Communications and Computer Skills Tools are introduced and then required throughout the four-year sequence to support the execution of design projects. The Engineering Ethics component provides students with a framework for understanding professional expectations and techniques for clarifying the ambiguity that is common in ethical dilemmas.

The primary purpose of the Professional Component course sequence is to link all these skills to engineering design and to assess the progress of student capabilities through the curriculum. The integrated structure of the Professional Component courses provides a framework for building upon previous coursework, assessing student progress often, and more quickly adjusting course coverage based on prior assessments to effectively assure that graduates of the program are capable of practicing as engineers upon graduation.

1. Introduction

The Professional Component as defined by EAC of ABET Criterion 4 has two major areas. The first area, Curricular Content, deals with whether the program provides the students with course-specific content in the areas of mathematics, basic science, engineering science, and General Education. The second area, Extra-Curricular, deals with the professional experiences of a student pursuing their degree: "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints." [1]

The engineering programs at WKU (Civil, Electrical and Mechanical) are new, with the first cohort of seniors currently progressing towards a May 2004 graduation. As an undergraduateonly engineering program, the ME faculty members at WKU place a strong emphasis on graduates possessing this Extra-Curricular professional competence. To achieve this outcome, it is necessary to provide students with the opportunity to acquire design tools and skills, as well as competency in mathematical and technical analysis, and communication. Throughout the four-year plan of study, the ME students receive coordinated instruction from both thermal-fluids and mechanical systems faculty, and are required to demonstrate varied levels of professional competence in both tracks.

The ME program employs Engineering Design, Computer Skills, Professional Communications, and Engineering Ethics as defined measures to quantify and assess Extra-Curricular experiences in the ME program. This has resulted in the formulation of the following plans:

- Engineering Design Plan (teaching and practicing of design skills)
- Professional Communications Plan (conveying designs and interacting with peers)
- Computer Skills Plan (teaching and implementing of design tools)
- Engineering Ethics Plan (evaluating and practicing appropriate professional behavior)

The development of these plans serves several purposes. None of the desired student professional outcomes are completely provided within a single course. It is necessary to coordinate the efforts of multiple faculty members across all four years of the curriculum to assure that students are successful in developing these skills. It is also necessary to assess the results and progress of students as they move through the curriculum. These outcomes can be difficult to precisely define and therefore assess, and in an effort to expend appropriate resources for this task the ME faculty anticipate efficiencies from agreed-upon descriptions and measurement tools across the curriculum.[2] Finally, the opportunity exists to make adjustments along the students' development path. Instead of observing a shortcoming in professional skills in a senior year capstone course, measured results in the earlier years can allow timely corrections to be made. This allows for the capstone course to be a truly integrative experience instead of last minute attempts to introduce the necessary professional skills. The following sections discuss the Extra-Curricular Plans in greater detail.

2. Engineering Design Component

The Design Plan developed by the ME faculty recognizes that the Engineering design process must be integrated into the ME curriculum as a continuous process from the first year to the final semester. This is necessary to provide students with the opportunity to acquire design tools and skills, as well as competency in mathematical and technical analysis, and communication.[3]

The ME faculty acknowledges the following attributes of Engineering Design taught in this department:

- Engineering design is the systematic application of the basic sciences, mathematics and engineering sciences to generate and evaluate specifications for systems, components, or processes.
- The form and function of the design must achieve defined objectives and satisfy consumer constraints.

- Design includes aspects of creativity, complexity, and iterative decision-making to optimize solutions, and compromise between multiple, sometimes conflicting, needs.

Components of the above statement were taken from several sources.[4,5,6] The following lists of Elements and the Features of Design, as specified by ABET, provide a framework that is used throughout the curriculum:

Elements:

- Objectives/Criteria
- Synthesis
- Analysis
- Construction
- Testing
- Evaluation

Features:

- Creativity
- Open-ended problems
- Design Theory
- Formulation of Problem/Specifications
- Alternative solutions
- Feasibility
- Manufacturing
- Concurrent engineering
- Realistic
- Codes/Standards
- Liability
- Written/Oral reports

Designated classes within the ME curriculum have specific design components included. These design experiences either introduce or reinforce the Engineering design process, combining a structured approach to solving problems with an appreciation for the art of engineering. Freshmen are expected to create physical devices with minimal engineering science, developing a sense of the manufacturing skills required for realistic designs. Progressively more complex projects are given to sophomores and juniors, requiring the use of engineering science gained from the curriculum. The seniors must design and implement external industry-based projects subject to realistic constraints and customer needs. Table 1 shows these courses, which are spread throughout the four years of the ME curriculum. For each design class, the primary design objectives have been identified allowing coordination of design throughout the curriculum.

Engineering Design Course	Credits
ME101 Freshman Experience	1
ME200 Sophomore Design	2
ME331 Strengths Lab	1
ME300 Junior Design	2
ME310 Engineering Instrumentation and Experimentation	1
ME344 Mechanical Design	3
ME400 Mechanical Engineering Design	2
ME420 Mechanical Engineering Lab I	3
ME411 ME Vibration/Controls Lab	1
ME430 Mechanical Engineering Lab II	3
ME412 ME Senior Projects	3

Table 1: List of Engineering Design Courses

The structure for measuring and assessing student performance in this component is provided within the overall ME program assessment. Engineering Design is an aspect of four of the thirteen ME Program Outcomes, which then support three Program Objectives. The assessment of the Program Outcomes will be discussed in section 6.

3. Professional Communications Component

The ME faculty divides the aspects of technical communication into the following three major areas, each of which must be satisfied for the completion of professional skills of our graduates:

- Written
- Oral
- Computer/Graphical

Designated courses within the ME program include communication skill components and provide instruction in or require the use of these skills. Some of the Written and Oral Communication skills instruction is provided outside of the ME curriculum, however students must clearly demonstrate the ability to use these skills toward Mechanical Engineering activities. The ME Faculty do not believe that a specific Technical Report writing course can provide students with the necessary writing skills, and that professional writing must be incorporated throughout the curriculum.[7] Furthermore, Computer/Graphical Communication represents the ability to effectively convey the results of student engineering activities to various audiences. Students develop hand-sketching skills early in the program, and move to more advanced computer drawing tools later in the curriculum. These and other computer tools are discussed in the next section.

Table 2 shows courses with an emphasis on Professional Communications, spread throughout the four years of the ME curriculum. As with the design courses, the primary Professional Communications objectives have been identified allowing coordination of the experiences and their corresponding assessment and timely improvement throughout the curriculum.

Professional Communications Course	Credits
UC175/ME101 Freshman Experience	3
ENG100, 200, 300 (General Education English)	9
COMM161 Business Speaking	3
ME200 Sophomore Design	2
ME331 Strengths Lab	1
ME300 Junior Design	2
ME344 Mechanical Design	3
ME400 Mechanical Engineering Design	3
ME412 ME Senior Projects	3
ME420, 430 Senior ME Lab I & II	6
ME411 ME Vibration/Controls Lab	1

Table 2: List of Professional Communications Courses

The assessment of Professional Communications is an aspect of two of the thirteen ME Program Outcomes, which will be discussed in section 6.

4. Computer Skills Component

The Computer Skills Plan developed by the ME faculty addresses the computer skills and technical software integrated into the ME curriculum. These tools were carefully selected to provide and support competency in mathematical and technical analysis, communication, and design. Through numerous courses in the four-year plan of study, the students receive instruction and are required to use computers and software for completing a range of increasingly advanced assignments. An appropriate level of student proficiency is expected in these experiences throughout the Mechanical Curriculum.

The ME faculty acknowledges the following statements regarding the integration and attributes of computer and software skills taught and used in this department:

- Students receive instruction in at least one structured language, which will be appropriate for performing technical analysis and design.
- Students receive instruction in commercially available software programs and use the software throughout the curriculum.

Three primary software programs are used within the ME program: SolidWorks 2003, MathCAD and MATLAB. During the summer of 2003, the ME program SolidWorks software suite was upgraded to SolidWorks 2003, which integrates Computer Aided Design capabilities with COSMOSWorks Design Analysis. The SolidWorks and COSMOSWorks suites are intended to provide the students with the tools necessary to create and improve designs through the parametric evaluation of a solid model of their design. This complements both an analytical solution approach, which is often limited to simple geometries, and an experimental solution, which have cost and physical limitations.

The COSMOSWorks analysis capability is a recent addition to the SolidWorks software suite and has not been fully integrated. These tools are being introduced in either specific courses (SolidWorks CAD) or as subset of courses (i.e., dynamic analysis, heat transfer and fluid analysis) throughout the four years of the curriculum. Building upon their background in sketching in the freshman year, students use SolidWorks for graphical design and advanced analysis in the later years of the curriculum. Students are expected to not only develop and improve designs using SolidWorks, but to also convey these designs to various audiences, including fabrication shops.

MathCAD and MATLAB software provide tools to implement iterative calculations, to visualize solutions, and to solve simultaneous equations, which support the typical requirements of engineering design. Students receive basic level instruction in the use of all of these software packages in the sophomore and junior years, and the use of these packages is built upon in successive classes within the ME curriculum. In addition, MATLAB's SIMULINK toolbox complements the dynamic system analysis capability of COSMOSWorks, providing the student with another method to verify their designs.

Other technical analysis packages are introduced and used throughout the ME curriculum as appropriate, and in addition, students will be expected to use word processing software, presentation software, and spreadsheet software in numerous courses – this is begun in the Freshman Experience courses. Use of e-mail and the Internet will also be expected, though specific instruction will not typically be given. Table 3 illustrates courses with a designated Computer Skills component. Note that only one course is a traditional computer science course; the others are courses that integrate these computer tools into various design experiences. In addition, since five of these courses are in the engineering department, assessment and course improvement is an integral part of the course.

Computer Skills Course	Credits
UC175/ME101 Freshman Experience	3
CS245 Intro. to Computer Programming Language, C	1.5
AMS205 CADD for Manufacturing	3
ME200 Sophomore Design	2
ME300 Junior Design	2
ME400 Mechanical Engineering Design	3

Table 3: List of Computer Skills Courses

The assessment of Computer Skills is an aspect of two of the thirteen ME Program Outcomes, which will be discussed in section 6.

5. Professional Ethics Component

The Professional Ethics Plan developed by the ME faculty addresses the need to convey professional behavior expectations to the students as a continuous process consistent with their level in the curriculum. The primary components of ethics covered are:

- Profession and Nature of Engineering
- Ethical Theories
- Assessing Safety and Risk
- Implications of Responsibilities
- Problem Solving Techniques

The above components have been taken from several sources.[8,9] Five courses in the four-year plan of study have ethics components, where the students receive instruction and are required to demonstrate an appreciation of ethical circumstances and to apply problem solving techniques. The students' awareness of professional ethics is expected to evolve from an understanding of professionalism and knowledge of standards of behavior, to the learning and application of ethical dilemma resolving methods. The transition over the curriculum also occurs from classical ethical cases to individual professional responsibilities. Table 4 lists courses with a Professional Ethics component. The team-based nature of these classes provides a forum for group discussion and resolution of ethical situations. As with the Computer Skills courses, the use of courses within the ME program provide an excellent opportunity for assessment and improvement of the student experiences. These courses also complement the General Education component at WKU.

Professional Ethics Course	Credits
ME101 Freshman Experience	1
ME200 Sophomore Design	2
ME300 Junior Design	2
ME400 Mechanical Engineering Design	2
ME412 ME Senior Projects	3

Table 4: List of Professional Ethics Courses

The assessment of Professional Ethics is the sole aspect of one of the thirteen ME Program Outcomes, which will be discussed in the following section.

6. Program Outcomes and Assessment

The ME faculty members have developed and are measuring and assessing thirteen Program Outcomes that encompass ABET outcomes a-k, as well as particular program expectations. The Extra-Curricular Professional Component is the focus of five of the thirteen Program Outcomes, which are shown in Table 5.

ME Program Outcomes
Professional Skills
4. Mechanical Engineering graduates can use structured problem solving techniques, appraise the needs of clients, produce product/project definition statements, and propose appropriate engineering solutions. 5. Mechanical Engineering graduates can execute a design from inception through completion, and convey/document solutions in a wide variety of formats.
Engineering Professionalism
6. Mechanical Engineering graduates can successfully manage projects. 7. Mechanical Engineering graduates can participate effectively in multi-disciplinary teams. 8. Mechanical Engineering graduates can judge appropriate professional and ethical conduct.

Table 5: Partial List of ME Program Outcomes

The assessment of each outcome is achieved using a variety of measures, including evaluation of selected student work, performance of students in extra-curricular activities, student exit interviews and composite student grades in appropriate courses. Faculty evaluation of outcomes takes place in two forms. Each semester, faculty members hold a Peer Review of Course Effectiveness session to review every engineering course taught in the program. The primary function of the Peer Review is to improve course outcome delivery; however the integration of the courses across the curriculum is also discussed. The second review is performed annually, where the faculty reports and discusses the data gathered for each Program Outcome.

For the Program Outcome reviews, the most important measure of student performance is through the evaluation of collected student work using assessment rubrics. Representative rubrics for two of the Program Outcomes are shown in Tables 6 and 7 below. The same rubrics are used for all years of student evaluation, allowing the comparison of varied levels of professional competence as students progress through the curriculum. The expected Total Score indicated at the bottom of either rubric table changes, reflecting the increasing expectation for student performance as they move through the elements of the integrated Professional Component.

Attributes	**Absent (0)**	**Novice (1):** some elements are present.	**Intermediate (2):** most elements are present	**Proficient (3):** all elements are present
Define project: Create clear statement of constituents, criteria and constraints.				
Manage solution definition: Be able to create design options, evaluate and implement preferred solution.				
Team Dynamics: Be able to divide the workload, monitor and convey progress to teammates, reach team decisions and integrate into final project.				
Peer Evaluation: Be able to evaluate performance of teammates and demonstrate effectiveness.				
Final results: Be able to complete projects within acceptable time, quality and cost constraints.				
Total Score: Expect 8 for Sophomore class, 10 for Junior Class and 12 for Senior Class				

Table 6: Project Management (Outcome 6) Rubric

The Table 6 Rubric is applied to a representative sample of student projects in the four sophomore, junior and senior design classes. The student work is independently evaluated by several ME faculty members and then discussed together. The results of this analysis support both the Engineering Design and Professional Communications components of the Professional Plan. The Table 7 Rubric is also applied to a representative sample of student work in the five freshman, sophomore, junior and senior design classes, and the results of this analysis supports the Engineering Ethics component of the Professional Plan.

Attributes	**Absent (0)**	**Novice (1):** some elements are present.	**Intermediate (2):** most elements are present.	**Proficient (3):** all elements are present.
Organization/Coherence: Statement of ideas is grammatically correct, professionally formatted. Author's intent is clear.				
Identify constituents: Clear indication of the parties impacted by the ethical dilemma.				
Describe purpose/dilemma: Ethical dilemma described, implications are conveyed.				
Develop resolution/solution: Methods for resolution are presented, comparisons made between solutions, and alternatives discussed.				
Total Score: Expect 5 for Freshman class, 6 for Sophomore class, 8 for Junior Class and 10 for Senior Class				

Table 7: Professional and Ethical Conduct (Outcome 8) Rubric

For each sample of student work, faculty members independently assign scores of 0 – 3 (absent to proficient) for each attribute component in the rubric. The sum of these scores for all attribute components becomes the total score. Freshmen and sophomores are expected to attain a novice to intermediate level, while seniors are expected to attain an intermediate to proficient level. The average values of student performance, assessed by several faculty members provide the basis for the student work evaluation used in the Professional Plan reports.

Rubric-based assessment of representative student work, coupled with assessment of student extra-curricular activities, student exit interviews and composite student grades provides the basis for the ME faculty members to evaluate the overall student progress in the Professional Plan, and adjust the delivery of the components as necessary.

7. Conclusion

The implementation of an Extra-Curricular Professional Component Plan at WKU has been completed with the initial execution of the first cohort of senior classes. Freshmen, sophomore and junior classes have been taught at least two times now. Assessment of student work and the results of the Peer Review of Course Effectiveness show that students are exhibiting an improved performance in the four areas of the Professional Component. Students nearing graduation are able to demonstrate competence in the four areas at a level consistent with the expectations of the faculty and external program constituents.

The integrated Professional Component Plan comprised of Engineering Design, Professional Communications, Computer Skills Tools, and Engineering Ethics has been instrumental in establishing a framework of student and program assessment. This assessment and course modifications process allows for continuous improvement in the program's effort to prepare the graduates for the baccalaureate practice of Mechanical Engineering. The Plan will continue to be a cornerstone of the program's ABET assessment plan.

Bibliography

1. 2004-05 Engineering Criteria, Accreditation Board for Engineering and Technology, Baltimore. (http://www.abet.org/criteria.html)
2. Senerty, E.M. "Assessment: How Much is Too Much or How Much is Not Enough?" ASEE Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition
3. Shetty, D. and Coleman, S. "Interpretation Of Engineering And Non-Engineering Skills During Transition From Being A Freshman To A Graduating Engineer" ASEE Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition
4. Lumsdaine, E., Lumsdaine, M., and Shelnutt, J.W., Creative Problem Solving and Engineering Design, Dubuque, Iowa: McGraw-Hill Primis, 1996.
5. Dym, C.L. and Little, P., Engineering Design: A Project-Based Introduction, New York, J. Wiley and Sons, 2000.
6. Dieter, G.E., Engineering Design, Boston, McGraw-Hill, 2000.
7. Untener, J. and Reynolds, M. "A Systemic Approach to Integrating Technical Writing in the Curriculum" ASEE Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition
8. Schinzinger, R. and Martin, M.W., Introducing Engineering Ethics, New York: McGraw-Hill, 2000.
9. Fleddermann, C.B., Engineering Ethics, Upper Saddle River, NJ: Prentice Hall, 1999.

CHRIS BYRNE
Chris Byrne teaches mechanical systems courses in Mechanical Engineering at WKU. This includes engineering science courses from the freshman to senior year of the program. He is active in research and industry outreach, with specialization in materials science, friction and wear mechanisms, and non-destructive evaluation. Prior to teaching at WKU, he was a faculty member of Southern Illinois University.

ROBERT CHOATE
Robert Choate teaches thermo-fluid and professional component courses in Mechanical Engineering, including the Sophomore Design, Junior Design, the Senior ME Lab I and the ME Senior Project Design course sequence. Prior to teaching at WKU, he was a principal engineer for CMAC Design Corporation, designing and verifying thermal management solutions for telecommunication, data communication and information technology equipment.

JOEL LENOIR
Joel Lenoir is the Layne Professor of Mechanical Engineering at WKU, and primarily teaches in the dynamic systems and instrumentation areas of the curriculum. His industrial experience includes positions at Michelin Research and Oak Ridge National Laboratory, as well as extensive professional practice in regional design and manufacturing firms.

KEVIN SCHMALTZ
Kevin Schmaltz teaches thermo-fluid and professional component courses in Mechanical Engineering, including the Freshman Experience course, Sophomore Design, Junior Design and the Senior Project Design course sequence. Prior to teaching at WKU, he was a project engineer for Shell Oil, designing and building oil and gas production facilities for offshore platforms in the Gulf of Mexico.