I. Pedagogical Plan Purpose and Overview
In order to support the School’s mission, and to ensure the best possible education, the mechanical engineering faculty have developed the following pedagogical plan. In order to continually improve the program it is important to define learning strategies; how it is that we help students achieve the required outcomes. This is not an assessment plan but rather describes in an overall, high level sense how the outcomes are integrated into our program. This plan includes all courses that our students take: those that are taught within the School, as well as math and science courses and University core courses.

The student outcomes are broad descriptions of the characteristics or abilities all of our graduates have attained. It requires a comprehensive curriculum to help students achieve any single outcome. There are eleven identified student outcomes; multiple classes are used to help students achieve each outcome. Most classes help students develop abilities associated with more than one outcome.

Cohesive Curriculum, Unique Faculty
It has been the focus of mechanical engineering faculty for several years to make the curriculum highly cohesive. This is a key characteristic of our pedagogical plan for each student outcome. While we maintain traditional subject-specific courses, we are striving to unify them; connecting them so that students gain an awareness of the multi-discipline nature of engineering. This also allows us incorporate various aspects of a given student outcome strategically within the curriculum.

Achieving our goals can only be accomplished with the full cooperation of the entire program faculty and staff. The Donald P. Shiley School of Engineering is fortunate to have such dedicated and talented educators who truly put the needs of the students above all else. The small size and focused dedication to undergraduate education uniquely positions the Shiley School’s faculty to achieve high standards.

II. Background

Donald P. Shiley ’51 provided the following advice to students:

"Find the gift God gave you. Sharpen, hone, and train it. And, then go use it. Go!"

II.a The School’s Mission:  
The School’s mission is to provide the best possible education to our students, thus enabling the students to become competent practicing engineers and computer scientists. The programs also provide a base for both graduate study and lifelong learning in support of evolving career objectives. These objectives include being informed, effective, and responsible participants in the engineering profession and society. The School endeavors to develop qualities that are essential for the practice of engineering and beneficial service to the community. These qualities include knowledge of engineering principles, the ability to apply those principles to solve problems, and the development of professional, personal, and social values.
In support of the School’s mission, our focus is to prepare engineers to solve technical problems that affect society. Students are prepared to tackle these complex technical challenges because our program of study includes both the technical fundamentals as well as the breadth of the liberal arts, combined with hands-on applications, oral and written communication practice, and faculty and staff who are dedicated to providing the best education possible. We believe students receive a well-balanced broad education that provides the necessary depth in traditional mechanical engineering subjects. Both breadth and depth are required for solving complex engineering problems.

II.b University Core Curriculum
The University’s Core curriculum is an essential element of our pedagogical plan. The goals of the core support several of our student outcomes, but have additional outcomes as well. From the University’s bulletin, the Core Curriculum is described as:

*The Catholic intellectual tradition is rooted in reasoned inquiry that crosses scholarly disciplines to engage and inform each of them. This tradition creates a framework in which great questions facing humankind can and should be addressed.*

*Through the core curriculum at the University of Portland students learn to use and value the lenses of different disciplines, see connections among them, and in doing so acquire the skills, knowledge, and values necessary for them to recognize the importance of broad learning and regular reflection throughout their lives. The goals of the core serve its mission and are achieved through the learning outcomes, which are continuously assessed.*

*The faculty is committed to teaching students essential skills and values for learning and life. Writing, oral communication, critical thinking, information literacy, and the implications of diversity are core skills distributed throughout the core curriculum. Students will thus have opportunities in their core courses to learn and refine their understanding and application of each of these skills.*

*There are five goals established for the Core:*

**Goal I:** Develop the foundational knowledge and skills necessary for informed inquiry, decision-making and communication.

**Goal II:** Develop the knowledge and skills for acting ethically in everyday life.

**Goal III:** Examine faith, its place in one’s life, and in the lives of others.

**Goal IV:** Critically examine the ideas and traditions of western civilization.

**Goal V:** Learn to live and contribute in a diverse society and interdependent world.

Learning outcomes have been established for each of the Core’s goals and specific outcomes are described at relevant locations in this pedagogical plan.
II.c University Resources
The University of Portland has a culture of collegiality. Faculty, staff and administrators from across campus work together to provide excellent education both inside and outside of the classroom. There are several centers on campus that help students achieve learning outcomes in various ways. These centers are a resource for faculty seeking pedagogical support, and they support students seeking extra-curricular development. It is common practice for the centers to provide guest lecturers and learning exercises within the program’s curriculum.

The Learning Resource Center
The Learning Resource Center serves the mission of the University by providing comprehensive learning support. The Center provides peer assistance for writing, math, speech, group process, and international languages, as well as a language lab and a professional learning assistance counselor. Faculty may require students to seek help from the Learning Resource Center and are provided feedback from the Center regarding outcomes identified from the interaction.

The Garaventa Center
The Garaventa Center fosters an ongoing conversation that is morally, ethically, and spiritually grounded, through a variety of programs including lectures, symposiums, art exhibits, and conferences. As Catholic, the Garaventa Center's commitment is informed by the values that stem from the recognition that all life is a gift from a loving Creator, that all human beings have intrinsic dignity, and that the goods of the earth and the goods of human ingenuity have been given by God for the sake of all God’s creatures. The Garaventa Center helps develop a culture on campus where ethics and professional responsibility are not just a classroom discussion topic.

Franz Center for Leadership, Entrepreneurship and Innovation
The Franz Center is dedicated to ensuring that all University of Portland graduates are prepared for the evolving challenges of the 21st century by supporting all students in the development of leadership, entrepreneurship, and innovation skills, knowledge and mindsets. The Franz Center provides extracurricular opportunities for students; most notably the e-scholar program helps students develop their entrepreneurship spirit. The Center is currently developing additional programs (in leadership and in innovation) and helps program faculty incorporate aspects of leadership and innovation within our curriculum.

The Moreau Center
The Moreau Center offers University of Portland students the opportunity to serve local, domestic, and international communities while developing the skills, knowledge, and habits to improve the world through hope, compassion and solidarity. Currently, the interaction between the Moreau Center and the mechanical engineering program is limited. However, the Center supports any students desiring to broaden their service-learning experiences.
II.d Strategic Continual Improvement

As part of regular assessment and subsequent evaluation of student outcomes, the mechanical engineering program continually makes changes to improve student education. Beyond tactical changes, we have strategic goals for continual improvement. Over the past several years, we have had two primary strategic goals: revise our curriculum to allow broader professional experiences, and develop a more cohesive curriculum to eradicate the stark boundaries between various subjects. Both of these are recommended by ASME’s Vision 2030 for Mechanical Engineering Education report (see Appendix V). We have thoroughly reviewed our curriculum and revised it to allow greater flexibility (starting with the 2013 incoming class). We have made significant strides towards a more integrated and cohesive curriculum; but work remains. The following are ongoing goals and tasks of the program faculty:

- Develop cross-curricular modules to integrate data acquisition and instrumentation within our laboratories and lectures.
- Evaluate the use of online portfolios for students. For example, we may require students to have a “design” portfolio where they post all of their design related work along with faculty comments regarding how to improve it. This could be a valuable educational tool that would bridge multiple classes, and it also provides students organized documentation that they could pull from to show potential employers.
- Work with the University’s Franz Center for Leadership, Entrepreneurship and Innovation to better incorporate leadership and innovation within our curriculum.
- Work with the Garaventa Center and other faculty on campus to better integrate “engineering ethics” within our curriculum.
- Working with Ms. Cathy Myers, Director of Industry and Community Partnership (a new position in the School) to develop the EGR300 Introduction to Capstone. We are also working with her develop employment opportunities, project opportunities, internships, etc.
- Develop opportunities for students to have more “hands-on” experiences. The opportunities for students to “get their hands dirty” have diminished substantially over the past several years. High school shop classes, working on automobiles, working on farms or in the woods have all become less common for today’s students. This is a concern as practicing engineers need to have good physical sense of the world. While this is not directly associated with any specific student outcome, it is still a concern to the faculty.

III. The Mechanical Engineering Curriculum

The curriculum has recently been reviewed and revised. The new curriculum has gone into effect with the incoming class of 2013. Courses have been added and other courses have been renumbered. One course was removed. For details, see the 2013 Annual Assessment and Evaluation Report for Mechanical Engineering. The following flow diagrams show the pre-2013 curriculum and the new curriculum.
IV. Application to Student Outcomes
The faculty, staff and administration function as a team to develop and deliver the best possible educational experience for the students at the Donald P. Shiley School of Engineering. The students are the reason for our existence. The following sections of this pedagogical plan describe how we help students achieve the eleven outcomes (“a through k”).
**Pedagogy for Student Outcome a: An ability to apply knowledge of mathematics, science, and engineering**

While all engineering, math and science courses have pedagogical elements for Student Outcome a, the most relevant courses for this student outcome are listed in Table A.1. These courses specifically apply knowledge of math, science and engineering learned in other courses to solve larger more complex problems. As students progress through the curriculum, the level of complexity increases.

Table A.1 – course listing for Student Outcome a

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course Details</th>
<th>Semester</th>
<th>Course Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>EGR111-Computer Applications</td>
<td>5th</td>
<td>ME301-Mech Engineering Analysis</td>
</tr>
<tr>
<td>1st – 4th</td>
<td>Math, 18 credits minimum</td>
<td>5th</td>
<td>ME304-Finite Element Analysis</td>
</tr>
<tr>
<td>1st – 2nd</td>
<td>Science Lecture courses, 9 credits minimum</td>
<td>5th</td>
<td>EGR311-Fluids I</td>
</tr>
<tr>
<td>3rd</td>
<td>EGR211-Statics</td>
<td>5th</td>
<td>ME331-Thermodynamics I</td>
</tr>
<tr>
<td>3rd</td>
<td>EGR221-Materials Science</td>
<td>6th</td>
<td>ME312-Fluids II</td>
</tr>
<tr>
<td>4th</td>
<td>EGR212-Dynamics</td>
<td>6th</td>
<td>ME332-Thermodynamics II</td>
</tr>
<tr>
<td>4th</td>
<td>EGR322-Strength of Materials</td>
<td>6th</td>
<td>ME336-Heat Transfer</td>
</tr>
<tr>
<td>4th</td>
<td>EE261-Electrical Circuits</td>
<td>6th</td>
<td>ME374-Fluids Lab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6th</td>
<td>ME401-Machine Design</td>
</tr>
</tbody>
</table>

In the first year, students study calculus, physics and chemistry. In the sophomore year, students study ordinary differential equations and vector calculus. This strong foundation in mathematics and science prepares students for advanced engineering courses typically taken in the third and fourth year.

Students apply knowledge of calculus and physics in courses such as statics, dynamics, and electrical circuits. In higher level engineering courses such as fluid mechanics and heat transfer, students apply knowledge of engineering and advanced mathematics to solve challenging engineering science problems.

The following are examples of required courses students take and the necessary prerequisites. Since calculus and physics are applied to solve statics problems, those courses are prerequisites for statics; et cetera.

- **Statics**: requires applying knowledge of Calculus I and Physics I
- **Dynamics**: requires applying knowledge of statics and Calculus II
- **Strength of Materials**: requires applying knowledge of statics
- **Materials Science**: requires applying knowledge of chemistry
- **Electrical Circuits**: requires applying knowledge of Physics II and Calculus II
Mechanical Systems Lab: requires applying knowledge of ordinary differential equations and dynamics.

Fluid Mechanics: requires applying knowledge of dynamics and calculus.

Finite Element Analysis: requires applying knowledge of engineering graphics, statics and dynamics.

Heat Transfer: requires applying knowledge of ordinary differential equations and introduces partial differential equations, and thermodynamics.

Machine Design: requires applying knowledge of dynamics to solve vibration and other such problems.

The above list is nowhere near exhaustive. Where appropriate, the faculty integrates math, science, and engineering topics into our upper division courses. The following is a simple example of how this may be achieved:

Through our assessment and evaluation process, in 2009 it was identified that seniors demonstrated poor understanding of dynamics. The action faculty took to resolve this situation was to increase the use of dynamics in upper-division courses. Specifically, dynamics problems (modal analysis, numerical modeling of mass-spring-damper systems, and centripetal forces of rotating machinery) were added to ME304 Finite Element Analysis and ME401 Machine Design to help student’s ability to apply dynamics to solve engineering problems.

Additional resource for help in mathematics: The Learning Resource Center serves the mission of the University and of the College of Arts and Sciences by providing comprehensive learning support including peer assistants for writing, math, speech, group process, and international languages, as well as a language lab and a professional learning assistance counselor.
**Pedagogy for Student Outcome b: An ability to design and conduct experiments, as well as to analyze and interpret data**

In the first laboratory course within the School (EGR270 Materials Lab), students are provided a copy of the Mechanical Engineering Laboratory Handbook, Donald P. Shiley School of Engineering (Appendix VI). This handbook was created by the program’s faculty to help students with general engineering laboratory educational needs and is used in the program’s laboratory courses. It includes Shiley School safety protocol, laboratory etiquette, discussion of measurement and test standards, calibration and certification of measuring devices, and discussion of how to create test plans and experiment plans.

The elements shown in Table B.1 are included in our courses in a systematic cohesive manner. Each of these is discussed in greater detail below.

<table>
<thead>
<tr>
<th>Course</th>
<th>Semester</th>
<th>Safety</th>
<th>Measurement calibration, test standards</th>
<th>Design, experiment, create plan</th>
<th>Conduct tests by following procedures</th>
<th>Data acquisition</th>
<th>Analyze and interpret data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Labs</td>
<td>1st, 2nd</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>EE271 Electrical Circuits Lab</td>
<td>4th</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>EGR270 Materials Lab</td>
<td>4th</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ME351 Mechanical Systems Lab</td>
<td>5th</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ME374 Fluid Lab</td>
<td>6th</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ME376 Thermo Lab</td>
<td>7th</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Cohesive Integration:** in order to help students understand the inter-connections in various courses and laboratories, and to develop their writing ability, in 2010 the faculty started requiring students to maintain a 3-ring laboratory notebook. This notebook contains all work from the four required laboratory courses in the program (materials science, mechanical systems, fluids, and thermal labs). It is meant to act as a self-created reference for students to develop their communication and laboratory skills. Faculty are considering replacing this with on-line portfolios.
FIRST AND SECOND SEMESTERS:

Science Laboratories (CHM277, PHY274, PHY275)

Safety: Students are introduced to the use of MSDS’s or SDS’s: (Material) Safety Data Sheets and basic safety protocol associated with chemical and mechanical hazards (including appropriate use of personal protection equipment).

Conduct Tests by Following Procedures: students work on a variety of basic science labs collecting and analyzing data.

FOURTH SEMESTER:

EE271 Electrical Circuits Laboratory

Safety: Hazards are generally minimal. At least one lab has potential for injury. For that lab, students are required to use appropriate personal protection equipment (safety glasses).

Follow Laboratory Procedures: All of the lab experiences require student to follow prescribed procedures.

Data Acquisition: students use equipment and instrumentation common in a well equipment electrical lab: oscilloscopes, function generators, power supplies, and DMM’s (digital multi-meters).

Analyze and Interpret Data: All of the lab experiences require student to analyze and interpret data. Students are required to compare measured values with expected or calculated values. This helps them understand the real variability that exists in physical systems and components.

EGR270 Materials Laboratory

Safety: Hazards in this laboratory include extreme heat, fracturing metallic test specimens, and exposure to acids. Before each laboratory, the appropriate safety measures are discussed and students must wear appropriate personal protective equipment.

Measurement Standards: A lecture is dedicated to discussing the seven physical variables comprising the primary measurement standards (mass, time, length, temperature, amount of a substance, light intensity and electrical current). The role of ISO and NIST are explained. Calibration and certification of measurement devices is discussed. Students use calipers to measure the diameter of a test bar and use a calibration block to validate the measurement. NIST-traceable hardness calibration blocks are used in several labs.

Test Standards: The purpose and use of test standards (such as ASTM) are discussed in a lecture. During the semester, students are required to design an experiment and to utilize at least one ASTM standardized test as a guide.

Design experiment, create plan: As a team of about three students, students design an experiment to investigate a simple materials related question (such as what may cause pitting corrosion in 2024-T3 aluminum). They are required to define the experiment’s objective, conduct a literature search, identify at least one relevant
ASTM standardized test, and create a test plan (that includes required samples and equipment, describe how the response variable will be measured, and a blank data sheet). They conduct the experiment and communicate the results at the end of the semester.

Conduct Tests by Following Procedures: The laboratory work is generally conducted as a group (the entire class of approximately 15 students and the instructor). The instructor provides written laboratory procedures and guides the students in conducting the work. Standardized tests are used where applicable:

- ASTM E8 – Standard Test Methods for Tension Testing of Metallic Materials
- ASTM E18 – Standard Test Methods for Rockwell Hardness of Metallic Materials (this includes the use of NIST-traceable hardness calibration blocks)
- ASTM A255-10 Standard Test Methods for Determining Hardenability of Steel

Data Acquisition: The students use and apply common measurement equipment for mechanical testing. The physical principles of the devices are discussed. The following are used by the students for acquiring data: calipers, strain gages, SATEC load frame (with load cells and LVDT strain indicator), Rockwell hardness testers, and Charpy Impact tester.

After being shown proper procedures, students demonstrate the ability to use sample preparation equipment and light microscopes for preparing and looking at metallurgical specimens.

Analyze and Interpret Data: In at least six different laboratory exercises, students analyze and interpret data. Typically, the data involves characterizing material properties (hardness, strength and/or toughness) as a function of heat treating, cold working, differing alloys, or test temperature. Their results are communicated in technical memos or in assigned worksheets.

**FIFTH SEMESTER:**

**ME351 Mechanical Systems Laboratory**

Safety: Hazards in this laboratory include mechanical motion and electrical power. Safety precautions are discussed including use of kill switches, mechanical shielding (guards) and use of safety glasses.

Design Experiment, Create Plan: Students use laboratory equipment to solve an open-ended engineering problem. They are required to identify a problem that involves using sensors and actuation in order to be solved. They design the solution, build a proof-of-concept prototype, determine how to test it in the lab, and demonstrate its function.

Data Acquisition: Students are shown how to use LabVIEW. They are required to write the LabVIEW code to acquire, plot, compare to a threshold, and save temperature data.
**SIXTH SEMESTER:**

**ME374 Fluid Laboratory**

**Safety:** Hazards in this laboratory include mechanical motion. The necessity of appropriate safety-shields is discussed.

**Measurement Calibration:** calibration is conducted on Venturi meters.

**Design Experiment, Create Plan:** each team of students plans and leads three or four experiments during the semester. They meet with the instructor prior to lab to ensure their plan will adequately satisfy the requirements.

**Conduct Tests by Following Procedures:** students must conduct approximately 10 different labs through the semester. Most of the labs have established laboratory procedures (either pre-established or established by other students).

**Data Acquisition:** analog measurement devices are used to acquire electrical power consumption of a pump motor (current and voltage data), motor RPM (using tachometer), pressure, drag forces in a wind tunnel, and flow velocity using Venturi meters and flow plates.

**Analyze and Interpret Data:** Data is collected and analyzed in approximately 10 laboratories.

**SEVENTH SEMESTER:**

**ME376 Thermo Laboratory**

**Safety:** Hazards in this laboratory include heat, pressure, chemical exposure and noise. The dangers associated with pressure vessels are discussed. The proper use of personal protective equipment is required.

**Measurement Calibration:** Various thermocouples (type K, T, with and without reference ice bath) are calibrated using a NIST certified thermistor. The measurement uncertainty of the various devices are estimated and compared with each other.

**Design Experiment, Create Plan:** Students plan part of several labs and conduct three laboratory exercises given an open-ended problem.

**Conduct Tests by Following Procedures:** Student conduct four laboratory exercises from pre-existing laboratory procedures and compare results to analytical models.

**Data Acquisition:** Students, having learned the basics of LabVIEW programming for data acquisition in ME351, are required to do more advanced programming in this lab course. Specifically students write LabVIEW code to acquire a thermocouple signal, filter the signal for noise, calculate a 30 second average of the data, and write the results to a file for an experiment that last 90 minutes. The code is then used to collect data for two cooling cylinders and calculate the emissivity.

**Analyze and Interpret Data:** In addition to more “routine” data analysis, students are required to conduct experimental uncertainty and propagation of error analysis for this laboratory course. Students are encouraged to perform more robust data analysis for most experiments using MatLab since electronic data acquisition is performed during most of the labs.
Additional resource for laboratory work, resource web page:
Laboratory work is integrated throughout our program. This requires all faculty to be involved, and it requires multiple classes. To provide students with a common reference source, we have created the *Mechanical Engineering Student Reference Materials* web page ([http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm](http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm)). The web page includes resources for design work, project management, team work, laboratory work, and communication (writing, speaking, graphical). The following are (inactivated) links for the laboratory work:

**GENERAL LABORATORY**
- *Mechanical Engineering Laboratory Handbook*
- *Codes and Standards*
- *ASME Codes and Standards*
- *NIST home-page*
**Pedagogy for Student Outcome c**: An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

In order to understand the importance of multiple design constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability, students are required to take various courses both within and exterior to the School. Engineering Economic (EGR351) helps students understand socio-economic, political, and environmental issues. The University Core courses help students understand social and historical issues as well as ethics. While the University Core does not teach engineering design, students develop a greater sense of the world around them and see the more global issues relevant for engineering.

Goal V of the University Core curriculum: *Learn to live and contribute in a diverse society and interdependent world.* This goal has the following learning outcomes. *The student will be able to:*

1. Recognize how culture, social factors, psychological factors, religious factors, and/or communication shape the way we view the world and identify differences between and within societies and other diverse groups of people;
2. Recognize social, political, historical, economical, and/or religious factors contributing to cultural differences;
3. Demonstrate an understanding of religious, political, historical, and/or social concepts necessary to be informed and engaged citizens living in an increasingly interdependent world

“Design Spine” within Mechanical Engineering

ASME Vision 2030 for Mechanical Engineering Education (see Appendix V) encourages mechanical engineering programs to have a “design spine” or “design portfolio” in their curriculum where students experience design throughout all four years. In 2012 the program faculty reviewed our curriculum and identified where and how we do teach engineering design. We recognized that we indeed already have design elements throughout the curriculum but needed approach design in a more systematic manner. Towards that end, we developed the following pedagogical plan for Student Outcome c.

Design is inherent in engineering – yet it can be difficult to precisely define or describe what “engineering design” actually is. It is a process involving many steps, and typically involves teams of engineers and non-engineers. ABET in Criterion 5 (Curriculum) defines engineering design as follows:

*Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.*
ABET goes on to describe elements of design and curricular components:

**Fundamental elements of the design process include:**

- the establishment of objectives and criteria
- synthesis
- analysis
- construction
- testing
- evaluation.

**The engineering design component of a curriculum should include the following features:**

- development of student creativity
- use of open-ended problems
- development and use of modern design theory and methodology
- formulation of design problem statements and specification
- consideration of alternative solutions
- feasibility considerations
- production processes
- concurrent engineering design
- detailed system description.

In order to properly teach design, students must be involved with design throughout all four years of their curriculum. While few courses in the mechanical engineering curriculum are specifically “design courses”, all engineering courses develop various aspects of student’s ability to design. The culminating design experience is the capstone design course sequence.

**What are steps in “the design process”?**

Engineering projects may be broken into several distinct phases – although in reality, the phases overlap or may be different altogether. Design is rarely a linear process – it is iterative in nature. Each design project is unique – there is no one process to follow for design. In general, the design process can be described as: Define the problem (which includes establishing objectives and criteria, and developing a plan), synthesize math, science and engineering knowledge to develop alternatives, evaluate the alternatives (through testing, analysis, literature search, etc.) and synthesize knowledge to select the best alternative. This process starts with conceptual design and proceeds to ever-more refined details until the finished product or design has been completed.
Define and refine the problem: define the objectives, develop and revise criteria, create or revise the project plan

Develop and synthesize alternatives

Conceptual design

Parametric design

Detailed design

Define and refine design details

Evaluate alternatives and down-select the “best” alternative through analysis, testing, literature search, etc.

Figure C.1 – a flow diagram for engineering design.

The following tables map the courses to the fundamental elements of the design process (Table C.1) and to the features in the curriculum which facilitate student design skills (Table C.2).
Table C.1 – Mapping of courses to the fundamental elements of the design process.

<table>
<thead>
<tr>
<th>Define the Problem</th>
<th>EGR110</th>
<th>EGR212</th>
<th>EGR270</th>
<th>EGR322</th>
<th>ME111</th>
<th>ME304</th>
<th>ME312</th>
<th>ME331</th>
<th>ME332</th>
<th>ME336</th>
<th>ME351</th>
<th>ME376</th>
<th>ME401</th>
<th>Capstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gather information, identify and understand the needs of the real problem</td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X X</td>
</tr>
<tr>
<td>Set goals, objectives, define criteria for the solution to the problem</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X X</td>
</tr>
<tr>
<td>Establish criteria that includes multiple realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>X X</td>
</tr>
<tr>
<td>Develop a plan to solve the problem</td>
<td>x</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>X X</td>
</tr>
<tr>
<td>Document the results of this process</td>
<td>x</td>
<td>X</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X X X</td>
</tr>
</tbody>
</table>

| Synthesize Knowledge to Develop Alternatives                                     |        |        |        |        |       |       |       |       |       |       |       |       |       |         |
| Generate ideas and concepts (brainstorm, etc.)                                   | X      | X      | x      |        |       |       |       |       |       |       |       |       |       | X X      |
| Document the results of this process                                            | x      |        | x      |       |       |       |       |       |       |       |       |       | X       | X X      |

| Evaluate Alternatives                                                            |        |        |        |        |       |       |       |       |       |       |       |       |       |         |
| Evaluate through literature search                                              | X      |        | x      |        |       |       |       |       |       |       |       |       |         | X        |
| Evaluate through analysis                                                        | x      | X      | x      | x      |       |       |       |       |       |       |       |       | X X X   | X        |
| Evaluate through testing                                                         | x      | x      |       |       |       |       |       |       |       |       |       |       |         | X X X    |
| Document the results of this process                                            | x      | X      | x      | x      |       |       |       |       |       |       |       |       |         | X X X    |

| Synthesize Knowledge to Select Best Alternative                                  |        |        |        |        |       |       |       |       |       |       |       |       |       |         |
| Down select to best alternative based on evaluation of criteria                  | X      |        | x      | x      | x      |       |       |       |       |       |       |       | X       | X X X    |
| Evaluate details to make sure the alternative is acceptable                      | X      |        | x      | x      | x      |       |       |       |       |       |       |       |         | X X      |
| Document the results of this process                                            | x      | x      |       |       |       |       |       |       |       |       |       |       |         | X X X    |
| Practice the above in an iterative project                                       |        |        |        |        |       |       |       |       |       |       |       |       |         | X X      |
| Document the final results and conclusions                                       | X      | x      | X      | x      | X      | x      | x      | X      | x      | x      | X      | x      | X       | X X X    |

*Lower case “x” indicates minor coverage, upper case “X” indicates more extensive coverage.*
Table C.2 – Mapping of courses to curricular features

<table>
<thead>
<tr>
<th>Curricular Features:</th>
<th>Freshmen</th>
<th>Sophomore</th>
<th>Fall Junior</th>
<th>Spring Junior</th>
<th>Senior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of student creativity</td>
<td>EGR110</td>
<td>EGR212</td>
<td>ME331</td>
<td>ME312</td>
<td>ME376 Capstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EGR270</td>
<td>ME351</td>
<td>ME336 ME401</td>
<td>FA207</td>
</tr>
<tr>
<td>Use of open-ended problems</td>
<td>EGR110</td>
<td>EGR212</td>
<td>ME351</td>
<td>ME332</td>
<td>Capstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EGR270</td>
<td>ME336 ME401</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>EGR322</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development and use of modern design theory and</td>
<td></td>
<td>ME304</td>
<td>ME332</td>
<td>ME376 Capstone</td>
<td></td>
</tr>
<tr>
<td>methodology</td>
<td></td>
<td></td>
<td>ME336 ME401</td>
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<td></td>
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<tr>
<td>Formulation of design problem statements and</td>
<td>EGR270</td>
<td>ME351</td>
<td>ME401</td>
<td></td>
<td></td>
</tr>
<tr>
<td>specification</td>
<td>EGR322</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Consideration of alternative solutions</td>
<td>EGR110</td>
<td>EGR322</td>
<td>ME331 ME351</td>
<td>ME336</td>
<td>Capstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ME336 ME401</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feasibility considerations</td>
<td></td>
<td>ME111</td>
<td>ME331 ME351</td>
<td>ME376 Capstone</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>ME336 ME401</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production processes</td>
<td>EGR110</td>
<td>ME111</td>
<td>ME312</td>
<td></td>
<td>Capstone</td>
</tr>
<tr>
<td>Concurrent engineering design</td>
<td>EGR110</td>
<td>ME351</td>
<td></td>
<td></td>
<td>Capstone</td>
</tr>
<tr>
<td>Detailed system description</td>
<td>EGR110</td>
<td>EGR270</td>
<td>ME351</td>
<td>ME336 ME401</td>
<td>Capstone</td>
</tr>
</tbody>
</table>

**EGR110 – Introduction to Engineering.** The course is based substantially on a semester-long design project, culminating in a demonstration of their completed device during the last week of classes. Students demonstrate the ability to work on teams to conceptualize, design, build, and test a device capable of meeting requirements set forth by the faculty in a project description. The requirements include a stated goal, as well as physical, material, and time constraints. Students are provided with some materials, and can “purchase” additional elements as needed. The project emphasizes design of components, assembly of component parts. Multiple realistic constraints are imposed including costs, budgeting of time, team organization, and adherence to stated rules.
EGR212 – Dynamics. Students are required to develop and solve an application of class theory three times throughout the semester. The design components of this task include problem identification, solving, and documenting. Analysis of the result, often in comparison to observation or a priori knowledge, may lead to alternate approaches to modeling or solution methodology.

EGR270 – Materials Laboratory. This laboratory class requires students to design and conduct an experiment to study a basic materials related problem such as corrosion. Students clearly define the problem, establish goals for the experiment, develop a plan, identify required resources, evaluate alternatives for their testing through literature search (including ASTM test standards), conduct the experiment and document the results.

EGR322 – Strength of Materials. Students are required to solve an open ended problem such as determining the cross-section dimensions of a beam to carry a specified load. For this design problem, they are to compare the stresses in both cantilever and simply supported beams and compare various static failure theories. They are to include shear and moment diagrams and Mohr’s circle for stress at the maximum bending.

ME111 – Engineering Design Graphics. This course introduces students to the concept of geometric tolerances and how they relate to manufacturability and product cost. Students demonstrate an understanding of machining and assembly criteria by producing properly dimensioned and tolerated engineering drawings of components and assemblies.

ME304 – Finite Element Analysis. Students apply finite element analysis to design a simple plate structure with at least a pinned-connection. They are to constrain the hole directly and compare the results with modeling the joint by including contact with the pin.

ME312 – Mechanics of Fluids II. As part of the course requirements, students are required to design, build, and test a turbine to perform a task. They are provided a kit which essentially is a turbine wheel. The task is to lift a two or three kilogram weight through a distance of three meters using ten liters of water with a head of about five meters. They work as teams and at the end of the semester they demonstrate the project in front of the class and briefly discuss the design features. They go through several brainstorming sessions, analyze various options, consider the complexity of the alternatives, and choose the one best suitable from cost and or feasibility considerations.

ME331 – Fundamental Thermodynamics. To help students develop intuition for thermodynamic systems the class includes a small design-build-test project. Late in the semester the students are challenged to build a device for less than $20 that will convert the energy of a balloon to work. The work is measured by the known mass of paperclips. Students design the device and estimate the work the device will do using thermodynamic modeling. Students then test the devices in class and calculate the efficiency of the system (always terrible).
ME336 – Heat Transfer. Students design a thermal enclosure to insulate a small object. This project typically involves the use of household goods to design a thermal environment to keep a cup of coffee warm. The project is assigned early in the semester and the initial design is based only on a 1-D conduction model of the device. As knowledge grows, the students are encouraged to optimize the design using a more sophisticated Matlab model or FEA/CFD analysis of the design and advanced methods from the class like radiation. Near the end of the semester the devices are tested and the smallest temperature drop over the course of the class period is considered the best performer.

ME351 – Mechanical Systems Laboratory. Two design projects are incorporated in this class. One project requires PID design. Through simulation students observe the response of a system to a step input and then design a controller to meet desired response characteristics. The second project is originated by students in the area of assistive technology. Students identify an existing need and design a solution using sensors, actuators and appropriate pairing of hardware and software. Students build a proof-of-concept prototype, determine how to test the prototype, and demonstrate its function. This process is iterative and requires technical trouble-shooting at many steps before an acceptable solution is achieved.

ME376 – Thermodynamics Laboratory. This is the final design experience in the thermal science track. Students are challenged to build a “water boiler” that is optimized for the system. In practice this means that the teams are given a glass beaker and 3 birthday candles. They design a device to maximize the increase in water temperature during a 3 minute period. Students are required to build a model to predict the performance of the device and then test the device. The results are compared and the students discuss the pros and cons of the design, construction, and testing protocol.

ME401 – Machine Design. Students conduct a semester-long design project and complete several assignments that require parametric design analysis. Students use programming (such as MatLAB or Excel) to evaluate various design parameters and to select optimal characteristics of the parameter to meet design criteria. Through the design project, students demonstrate an ability to establish criteria, create a plan to solve the engineering problem, generate ideas and evaluate alternatives, conduct component testing and analysis, down-select best options based on multiple criteria and constraints, conduct testing of finished prototype and refine the design as needed. Students experience the iterative nature of design in the project from concept through final product definition.

Capstone Courses (ME481/482 or EGR483/484). These course sequences are the culminating design experience. Mechanical engineering students choose to either the mechanical sequence (ME481/482) or the multidisciplinary sequence (EGR483/484). Students in these courses experience the entire design process. They identify and formulate an engineering design problem, plan the project, and complete the design process. Students demonstrate a completed design either with a functioning prototype or through detailed documentation.
Additional resource for engineering design, resource web page:

Design work is integrated throughout our program. This requires all faculty to be involved, and it requires multiple classes. To provide students with a common reference source, we have created the Mechanical Engineering Student Reference Materials web page (http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm). The web page includes resources for design work, project management, team work, laboratory work, and communication (writing, speaking, graphical). The following are (inactivated) links for the design content:

**DESIGN PROCESS, PROJECT MANAGEMENT, TEAM WORK**

*Design? (author unknown)*

*ABET Definition of Design*

*Standard problem solving format (must be applied for all analysis, homework problems and especially design analysis problems)*

*Design Decision Documentation*

*Engineering Design Process*

*Project Planning using Key Characteristics*

*Design Considerations (from which criteria may be developed)*

*Concurrent design evaluation*

*Evaluating alternatives, developing criteria*

*Fail safe and safe life design philosophy*

*Scheduling (making schedules)*

*MS Project Basics (how to)*

*Example of a Schedule (Gantt Chart format)*

*What are Action Item Logs and Decision Logs*

*Action Item Logs*

*Decision Log*

*Meetings - how to run and manage them effectively*

*Concisely: meetings, agenda, minutes*

*Agenda example*

*How to manage a dysfunctional team*

*How to avoid procrastination - the number 1 killer of projects*

*Peer evaluations*

*Codes and Standards*

*Human Factor Design (from the news program “60 Minutes” – but takes only 10 minutes to watch) --- keep this in mind - what you design will be manufactured by someone and maintained by someone - make their life easier.*
Pedagogy for Student Outcome d: An ability to function on multi-disciplinary teams.

In several of the program’s courses, students must work on teams to accomplish various tasks. Table D.1 shows the team activity for relevant course. In most cases, teams are either selected by the faculty or self-selected (both approaches are used), have 3 to 4 students, and perform as a team through the entire semester.

Table D.1 – description of team experiences.

<table>
<thead>
<tr>
<th>Class</th>
<th>Semester</th>
<th>Team activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGR110 Intro to Engineering</td>
<td>1st</td>
<td>Design, construct and test a device to perform a specific task. Create written and oral reports.</td>
</tr>
<tr>
<td>PHY274, 275 CHM277</td>
<td>1st, 2nd</td>
<td>Students work in teams on various laboratory exercises</td>
</tr>
<tr>
<td>EGR270 Materials Laboratory</td>
<td>4th</td>
<td>Design, plan and conduct an experiment to study material properties. Create written and oral reports.</td>
</tr>
<tr>
<td>EE271 Electrical Circuits Lab</td>
<td>4th</td>
<td>Students work on teams of two to conduct laboratory exercises.</td>
</tr>
<tr>
<td>EGR322 Strength of Materials</td>
<td>4th</td>
<td>As teams, students design a truss to meet specified constraints, build and test the truss, and create a design report with dimensioned drawings.</td>
</tr>
<tr>
<td>ME351 Mechanical Systems Lab</td>
<td>5th</td>
<td>Students work on teams to produce results from four “prescribed” laboratory procedures and for a design project.</td>
</tr>
<tr>
<td>ME374 Fluids Lab</td>
<td>6th</td>
<td>Students work on teams to plan 3 or 4 experiments, produce and deliver pre-labs and post-labs reviews to the class, and produce one team project report.</td>
</tr>
<tr>
<td>EGR300 Intro to Capstone</td>
<td>6th</td>
<td>Students work on multi-disciplinary teams and develop a plan for a multi-disciplinary project. Guest speakers from the Center for Leadership, Entrepreneurship, and Innovation give talks on leadership and help students develop their own leadership skills (this class is still in development).</td>
</tr>
<tr>
<td>ME401 Machine Design</td>
<td>6th</td>
<td>Design, construct and test an electric powered vehicle to perform a specified task. Create written report.</td>
</tr>
<tr>
<td>ME376 Thermo Lab</td>
<td>7th</td>
<td>Students work as teams to produce several written lab reports and memos.</td>
</tr>
<tr>
<td>Capstone</td>
<td>7-8</td>
<td>See description below</td>
</tr>
</tbody>
</table>

Capstone: Students must work on teams of peers, faculty, and industrial advisors. This arrangement is similar to what occurs in practice: the faculty advisors play the role similar to a Project Lead Engineer, the course instructor has a similar role to an Engineering Manager, and the Industrial Advisors play a role equivalent to either a customer and/or a technical expert in a different company or department.
Teams are required to meet with their Industrial Advisor within the first few weeks of the semester. They are to discuss their project’s goals and plans. They are also required to discuss what the specific role of their Industrial Advisor will be (how often should they meet, how much technical support is expected, etc.). This helps facilitate the effectiveness of the different roles of individual project stakeholders.

Additionally, since 2011 the capstone courses have used “super-groups”. Super-groups are groups of three to five capstone project teams. They meet at least twice a semester to provide peer evaluation for each other’s projects. This helps students develop the ability to constructively evaluate someone else’s project, it helps them develop communication skills so that their project can be effectively evaluated, and it provides them an opportunity to receive and listen to comments and advice from peers. These are all important characteristics of effective team work and good communication skills.

**Additional Resource for engineering design:**
Teamwork is integrated throughout our program. This requires all faculty to be involved, and it requires multiple classes. To provide students with a common reference source, we have created the *Mechanical Engineering Student Reference Materials* web page ([http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm](http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm)). The web page includes resources for design work, project management, teamwork, laboratory work, and communication (writing, speaking, graphical). The following are (inactive) links for the teamwork:

**DESIGN PROCESS, PROJECT MANAGEMENT, TEAM WORK**

* Scheduling (making schedules)
* MS Project Basics (how to)
* Example of a Schedule (Gantt Chart format)

* What are Action Item Logs and Decision Logs
  * Action Item Logs
  * Decision Log

* Meetings - how to run and manage them effectively
  * Concisely: meetings, agenda, minutes
  * Agenda example

* How to manage a dysfunctional team
  * Peer evaluations

**Additional University resources available to students for developing team skills:**

- The *Learning Resource Center* serves the mission of the University and of the College of Arts and Sciences by providing comprehensive learning support including peer assistants for writing, math, speech, **group process**, and international languages, as well as a language lab and a professional learning assistance counselor.
• The University of Portland Franz Center for Leadership, Entrepreneurship, and Innovation supports students by lecturing in capstone courses about leadership and requiring students to reflect upon their own leadership abilities.
**Pedagogy for Student Outcome e:** An ability to identify, formulate, and solve engineering problems.

Engineering problems may be placed into two broad categories: “closed” problems which have a single correct answer and “open-ended” problems which do not. Engineers must be able to solve both.

The students in the mechanical engineering program receive a very strong foundation in both thermal and mechanical systems. They also receive an education in materials science (EGR221), electricity and magnetism (PHY205/275), electrical circuits (EE261/271), economics (EGR351) and liberal arts (University Core). We believe this is a well-balanced broad education that provides the necessary depth in traditional mechanical engineering subjects. Breadth and depth are both necessary for solving complex engineering problems.

Closed and Open-Ended Problems: Before solving any problem, engineers must have a thorough understanding of the physical principles involved. Most engineering courses require regular (weekly) assignments. Through this, students develop a deep understanding of the principles governing the given subject. Most of these exercises are “closed” problems. However, the mechanical engineering faculty has identified courses in all four years in which students systematically develop their abilities to solve more complex open-ended problems. Through this blend of “closed” and open-ended exercises, students develop a deep understanding of the subject and also develop the ability to apply that knowledge to solve complex engineering problems.

<table>
<thead>
<tr>
<th>Use of open-ended problems</th>
<th>Freshmen</th>
<th>Sophomore</th>
<th>Fall Junior</th>
<th>Spring Junior</th>
<th>Senior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EGR110</td>
<td>EGR212</td>
<td>ME304</td>
<td>ME332</td>
<td>Capstone</td>
</tr>
<tr>
<td></td>
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<td>EGR270</td>
<td>ME351</td>
<td>ME336</td>
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<tr>
<td></td>
<td></td>
<td>EGR322</td>
<td></td>
<td>ME401</td>
<td></td>
</tr>
</tbody>
</table>

Each of these courses and the pedagogical use of open-ended problems is discussed in detail in Pedagogy for Student Outcome c (design).

Problem Solving Process: Technical competence attained through solving closed and open-ended problems is necessary for engineers. However, the faculty adhere to the adage “the best ideas are worthless unless well communicated.” As part of learning to solve engineering problems, students (sophomores through seniors) are required on every problem on every assignment to follow the “standard mechanical engineering homework format.” Through this, students develop the habit of clearly stating the problem, showing they are aware of necessary assumptions, specifying the purpose of the work, showing all steps in the solution (citing references where needed), and highlighting their conclusion. In short, they learn to properly document their work. See Appendix II.

Program faculty work closely together to develop teaching methods and assignments that can be applied differently in multiple courses. For example, in ME304 Finite Element
Analysis, students are required to analyze stresses near a hole in a flat plate. They are asked to use finite element analysis to estimate the stress concentration at the hole. This same problem is used in ME401 Machine Design and students use stress concentration charts to determine the stress concentration. The pro’s and con’s of the two different methods (FEA and charts) are discussed.

The following is an example of multi-discipline assignment (ME401 Machine Design and ME304 Finite Element Analysis):

Consider the simple geometry shown below. Assume the load is uniformly distributed at the ends and that the stress on the edge is 500psi. Assume the plate is 0.500 inch structural steel with $E=30 \times 10^6$ psi and $\nu = 0.27$. Determine the maximum stress caused by stress concentration.

The bar is 2 inches wide, the hole is 1 inch diameter and is centered.

In ME304, students use finite element analysis to analyze and visualize the stress and in ME401 they use stress concentration charts to analyze the stress concentration. FEA has the benefit of allowing visualization of stress distribution and the stress concentration charts have the benefit of design utility.
Pedagogy for Student Outcome f: An understanding of professional and ethical responsibility

Students are required to develop an understanding of professional and ethical responsibility in all laboratory courses; proper and safe use of laboratories is demanded of all students and reinforced by faculty and staff. Outcome f is also addressed specifically in several lecture courses which are discussed below.

The following courses directly support pedagogy of Outcome f:

<table>
<thead>
<tr>
<th>Class</th>
<th>Pedagogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGR110-Introduction to Engineering</td>
<td>Introduce professionalism and associated responsibilities.</td>
</tr>
<tr>
<td>PHL220-Ethics</td>
<td>Develop strong foundation of philosophical theory</td>
</tr>
<tr>
<td>EGR300-Intro to Capstone</td>
<td>Apply ethics to engineering</td>
</tr>
<tr>
<td>Capstone sequence</td>
<td>Reflection of ethical and professional responsibility in their project.</td>
</tr>
</tbody>
</table>

EGR110 Introduction to Engineering: Students are introduced to professionalism and professional and ethical responsibility during their first semester at the University. Students explore what it means to be a professional engineer and they discuss one or more of the common engineering Code of Ethics (NSPE, ASME, etc.).

PHL220 Ethics: From the University of Portland’s Mission Statement:

...Because we value the development of the whole person, the University honors faith and reason as ways of knowing, promotes ethical reflection, and prepares people who respond to the needs of the world and its human family.

In support of the mission, all University students are required to take PHL220 Ethics. The course introduces major theories in classical and/or contemporary moral philosophy. Particular emphasis is placed on understanding and concretely applying normative theories of moral obligation.

Goal II of the University Core: Develop the knowledge and skills for acting ethically in everyday life. This goal has the following learning outcomes; the student will be able to:

1. Recognize the limits of relativism and absolutism;
2. Recognize the ethical dimensions of novel problems and situations;
3. Frame an ethical problem;
4. Analyze a problem or situation using various ethical theories;
5. Come to a tentative judgment about an ethical problem he or she has framed and analyzed;
6. Distinguish ethics from law.
PHL220 is a semester-long course devoted to the study of ethics.

**EGR300 Introduction to Capstone:** students apply theoretical ethics to real engineering situations. discuss various engineering case studies. These discussions are meant to help students understand the ethical complexity that is often associated with engineering activities. Details for this course are still being developed.

**Capstone Courses:** often, ethics is presented as a code of “avoiding bad behavior.” In capstone, we reverse this perspective. We view ethics and professional responsibility as a positive influence; each project is expected to somehow contribute to the greater good of the earth, its resources, and to humanity. Engineers are important stewards of creation. To help students understand this, each team gives a brief overview to the class of their project. While they are doing so, students in the class identify how the project contributes to the greater good or in some other way demonstrate ethical and/or professional responsibility. They write a one sentence description of that. These descriptions are shared with the teams so that they can see how their project is perceived by their peers in this respect. By the completion of their project, each team is required to reflect upon the ethical and/or professional responsibility evident in their project and to write a brief description of it.

**Additional Resource for professional and ethical responsibility:** The Garaventa Center fosters an ongoing conversation that is morally, ethically, and spiritually grounded, through a variety of programs including lectures, symposiums, art exhibits, and conferences. The Garaventa Center helps develop a culture on campus where ethics and professional responsibility are not just a classroom discussion topic.
Pedagogy for Student Outcome g: An ability to communicate effectively.

The mechanical engineering program integrates writing into the curriculum in a systematic manner so that students learn to communicate effectively within the context of various courses.

Holistically, effective communication must contain many elements: proper organization and structure (leading the reader or listener from general concepts to detailed conclusions), effective graphics (graphs, sketches, photographs, etc.), proper use of external sources (including citations and bibliographic information), clear analysis of data and interpreting it, valid conclusions, etc. Written engineering documents may be very concise (short technical memos and letters) or contain extensive details (reports). Various courses emphasize different aspects of communication. Table G.1 lists the courses within our program that emphasize written and/or oral communication.

To help students develop their communication skills, all freshmen engineering students are given a copy of the Donald P. Shiley School’s Writing for Engineers handbook (Appendix VII). This handbook describes the various forms of engineering documentation and oral presentations. The faculty requires students to use this resource for relevant assignments.

Since 2009 the mechanical engineering faculty has used common standards for concise letters/memos, reports, and oral presentations. For all communication assignments, students are provided a copy of these standards (see Appendix III). Written and oral communication is assessed holistically; based on how well the communication was achieved overall.

Cohesive Integration: in order to help students understand the inter-connections in various courses and laboratories and to develop their writing ability, in 2010-2011 the faculty started requiring students to maintain a 3-ring laboratory notebook. This notebook contains all work from the four required laboratory courses (materials science, mechanical systems, fluids, and thermal labs). It is meant to act as a self-created reference for students to develop their communication and laboratory skills. The faculty is considering replacing or augmenting this with on-line portfolios.
Table G.1 – mapping of courses to communication form.

<table>
<thead>
<tr>
<th>Course</th>
<th>Develop basic writing skills and utilizing evidence to support thesis</th>
<th>Engineering Drawings and/or sketches</th>
<th>Graphing data</th>
<th>Concise technical memos or letters</th>
<th>Engineering Reports (lab and design)</th>
<th>Engineering Project Plan</th>
<th>Formal Oral Engineering Presentation</th>
<th>Formal communication via email</th>
<th>Face-to-face communication in meetings with faculty and peers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENG112-Intro to Literature</td>
<td>I</td>
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<td>PHL150-Intro to Philosophy</td>
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<td>EGR110-Intro. Egr</td>
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<td>I</td>
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<tr>
<td>EGR270-Mat’l Lab</td>
<td>5I</td>
<td>1T,4I</td>
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<td>ME111-Egr Graphics</td>
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<td>ME301-Egr Analysis</td>
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<td>ME304-Finite Element Analysis</td>
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<td>ME332-Thermo II</td>
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<td>ME336-Heat Transfer</td>
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<tr>
<td>ME351-Mech Systems Lab</td>
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<td>1T,4I</td>
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<td>ME374-Fluids Lab</td>
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<td>ME376-Thermo Lab</td>
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<tr>
<td>ME401-Machine Design</td>
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<tr>
<td>ME481-Capstone Dsgn I</td>
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<td>1T</td>
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<td>ME482-Capstone Dsgn II</td>
<td>I</td>
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</table>

T – Team produced
I – Individual produced
T, I – the number preceding either the T or I is the minimum number of exercises in that class. If no number is identified, it means no specific quantity is required.

**EGR110 Introduction to Engineering:** engineering students are introduced to technical writing and oral communication. Each student produces engineering reports and in teams of 3 or 4 students give oral presentations to communicate their design.

**EGR270 Materials Laboratory:** almost all of the written communication work is done as individuals (there is one team produced memo). Emphasis is placed on appropriately
displaying laboratory data (typically graphs and tables), making strong valid conclusions, and concise writing (one page maximum to communicate laboratory results).

**ME111 Engineering Graphics:** students learn to communicate their design through engineering drawings (per professional engineering drawing standards). They also produce a design report discussing their design.

**ME301 Numerical Methods:** students write three concise memos discussing small projects.

**ME304 Finite Element Analysis:** each student is required to write a design report communicating the results of their design project. Typically, appropriate diagrams are included in the design report (sketches, shear and moment diagrams, Mohr’s circle, etc.) and results of the FEA work.

**ME351 Mechanical Systems Lab:** students write four individual memo’s and one team memo discussing their laboratory work. They also deliver, as teams, a formal oral presentation on their laboratory design work. Use of graphs is often required to communicate data.

**ME332 Applied Thermodynamics:** each student writes an in-depth research paper on an emerging topic in thermodynamics. The reports include 5 citations from the archival literature in the last 10 years.

**ME 336 Heat Transfer:** In teams, students write a report and a memo communicating the results of the heat transfer projects. The memo is an early design report that includes a sketch of the device. They are required to include dimensioned engineering drawings in the final formal report for the project.

**ME374 Fluids Laboratory:** students write several highly detailed laboratory reports. Most of these are as individuals, but at least one team produced report is also required. Students are also expected to write memos and give professional quality oral pre-lab and post-lab presentations to the class.

**ME376 Thermodynamics Laboratory:** most of the communication work in this course is team based. As a team, students write several laboratory reports and concise memos.

**ME401 Machine Design:** students are required to produce a project plan and complete a design report for a modest sized design project.

**ME481/482 Capstone:** each student is assigned to write a memo for their team project. As a team, they produce an engineering project plan, a design report, and give at least two formal engineering oral presentations. Teams have formal meetings with faculty instructor, faculty advisors and industrial advisors and are expected to have regular team meetings. They are required to communicate project progress to the faculty and advisors via concise emails (they learn to appreciate that there is a difference professional and
Each student is required to produce at least one engineering drawing (either detailed or assembly drawing) for their project.

Additionally, since 2011 the capstone courses have used “super-groups”. Super-groups are groups of three to five capstone project teams. They meet at least twice a semester to provide peer evaluation for each other’s projects. This helps students develop the ability to constructively evaluate someone else’s project, it helps them develop communication skills so that their project can be effectively evaluated, and it provides them an opportunity to receive and listen to comments and advice from peers. These are all important characteristics of effective teamwork and good communication skills.

University Core, embedded writing elements
The University places strong emphasis on developing student communication ability. Specific University Core courses contain so-called “embedded elements.” Two courses (ENG112, PHL150) contain writing embedded elements in which students are taught how to write thoughtful documents at the university level. They are required to demonstrate their writing abilities in both of these courses. The goals of the University Core curriculum that articulate communication include Goal I and Goal IV:

Goal I of the University’s Core Curriculum: Develop the foundational knowledge and skills necessary for informed inquiry, decision-making and communication. Learning Outcomes, students will be able to:
1. Express the product of critical, analytical, and imaginative thought in writing;
2. Use analytical and logical thinking in reading and presenting ideas and arguments;
3. Express the product of critical, analytical, and imaginative thought in speech;
4. Understand the concepts, principles, and implications of diversity and difference;
5. Find and use information to support the process of critical and analytical pursuits;
6. Use quantitative methods and perspectives to understand and solve real-world problems

Goal IV of the University’s Core Curriculum: Critically examine the ideas and traditions of western civilization. Learning Outcomes; student will be able to:
1. Critically read and examine significant texts and art of western civilization;
2. Write critically about significant texts and art of western civilization;
3. Speak critically about significant texts and art of western civilization.

Additional Resource for learning to communicate:
Effective communication is taught throughout our program. This requires all faculty to be involved, and it requires multiple classes. To provide students with a common reference source, we have created the Mechanical Engineering Student Reference Materials web page (http://faculty.up.edu/lulay/MEStudentPage/ME-Student-Page.htm). The web page includes resources for design work, project management, team work,
laboratory work, and communication (writing, speaking, graphical). The following are (inactivated) links for the communication content:

**GRAPHING, ENGINEERING DRAWINGS, PHOTOGRAPHY**
- Graphing of Engineering Data
- Graphing/Figure Standards
- Graph formatting
- Engineering Drawing Standard
- Example of a detailed drawing
- Example of an assembly drawing
- Photography for Engineering Reports

**WRITING and SPEAKING**
- Writing for Engineers (booklet)
- Memos and Letters
- Memo and letter content
- Proposals
- Laboratory Reports
- Design/Project Reports
- Technical Presentations
- Common writing mistakes that students make; Part I
- Common writing mistakes that students make; Part II
- Columnist Advice

**WRITING and SPEAKING EXAMPLES**
- Well written letter
- Poorly written letter
- Memo - good example
- Well produced oral presentation
- Poorly produced oral presentation
- Proposal memo example
- "Grade sheet" used by ME faculty for technical presentations

Additional University resource for learning to communicate:
The Learning Resource Center serves the mission of the University by providing comprehensive learning support including peer assistants for **writing**, math, **speech**, **group process**, and international languages, as well as a language lab and a professional learning assistance counselor.
**Pedagogy for Student Outcome h:** The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

This Outcome is unique in that it does not state what students are supposed to be able to do, but rather describes the education itself. The program’s curriculum provides the broad education within the School and through the University Core. Within the Shiley School of Engineering, several courses help broaden student education beyond the purely technical. The mechanical engineering students are required to take EGR351 Engineering Economics, EGR300 Introduction to Capstone, and two-semester capstone design sequence (either ME481/482 or EGR483/484); all of which provide broad education.

**EGR351 Engineering Economics:** Students are taught comprehensive concepts of engineering economics to address environmental, political, economic and social impacts of many engineering decisions, in both societal (a particular community) and global context.

**EGR300 Introduction to Capstone:** Students become more aware of the far-reaching impact engineering can have on all aspects of society. On “project pitch night” representatives from industry, government, non-profit organizations, and faculty provide students with viable projects that they can work on as seniors. Typical projects include assistive devices for the physically impaired, alternative energy or energy conservation, transportation, food production, and appropriate design for the third-world.

**ME481/482 Capstone Sequence:** Students discuss in class the global and societal context of the projects they have chosen. This helps students understand the potential impact of their project as well as the projects of their peers.

**The University Core:** the mechanical engineering students are required to take 27-30 University Core credits. Courses in history, social science, fine arts, philosophy and theology provide a broad education and help students to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>ENG112</td>
<td>Intro to Literature</td>
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<tr>
<td>FA207</td>
<td>Fine Arts</td>
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<tr>
<td>History</td>
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<tr>
<td>PHL150</td>
<td>Intro Philosophy</td>
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<tr>
<td>Social Science (6 credits)</td>
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<tr>
<td>THE105</td>
<td>Intro to Theology</td>
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<tr>
<td>THE205</td>
<td>Bible, Past and Present</td>
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</table>
From bulletin description of the Core curriculum:

The Catholic intellectual tradition is rooted in reasoned inquiry that crosses scholarly disciplines to engage and inform each of them. This tradition creates a framework in which great questions facing humankind can and should be addressed.

Through the core curriculum at the University of Portland students learn to use and value the lenses of different disciplines, see connections among them, and in doing so acquire the skills, knowledge, and values necessary for them to recognize the importance of broad learning and regular reflection throughout their lives. The goals of the core serve its mission and are achieved through the learning outcomes, which are continuously assessed.

Goal V of the University’s Core Curriculum: Learn to live and contribute in a diverse society and interdependent world. Learning Outcomes; the student will be able to:

1. Recognize how culture, social factors, psychological factors, religious factors, and/or communication shape the way we view the world and identify differences between and within societies and other diverse groups of people;
2. Recognize social, political, historical, economical, and/or religious factors contributing to cultural differences;
3. Demonstrate an understanding of religious, political, historical, and/or social concepts necessary to be informed and engaged citizens living in an increasingly interdependent world.
**Pedagogy for Student Outcome i: A recognition of the need for, and an ability to engage in life-long learning.**

Ultimately, every course helps students develop the ability to be life-long learners. In particular, students are required to pursue knowledge outside of the classroom on every laboratory memo and reports, design reports, project reports (required in most engineering electives), and to gain technical knowledge for various class projects (including ME351, ME401, and engineering electives).

Additionally, the University Core curriculum supports this student outcome. From bulletin description of the Core curriculum:

*Lenses for Seeing and Learning Essential Skills and Values: The faculty is committed to teaching students essential skills and values for learning and life. Writing, oral communication, critical thinking, information literacy, and the implications of diversity are core skills distributed throughout the core curriculum. Students will thus have opportunities in their core courses to learn and refine their understanding and application of each of these skills.*

Table I.1 – courses that require students to pursue independent learning outside of structured class (literature searches, etc.).

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<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>PHL150-Introduction to Philosophy</td>
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<td>ENG112-Introduction to Literature</td>
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<td>EGR110-Introduction to Engineering</td>
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<td>EGR111-Engineering Computing with Applications</td>
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<td>EGR270-Materials Lab</td>
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<td>EGR300-Introduction to Capstone</td>
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<td>ME332-Applied Thermodynamics</td>
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<td>ME336-Heat Transfer</td>
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<td>ME351-Mechanical Systems Lab</td>
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<td>ME374-Fluids Lab</td>
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<td>ME376-Thermo Lab</td>
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<td>ME401-Machine Design</td>
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<td>Capstone</td>
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Pedagogy for Student Outcome j: A knowledge of contemporary issues.

**EGR351 Engineering Economics:** Students learn about non-technical contemporary issues such as socio-economic, political, and environmental.

**EGR300 Introduction to Capstone:** Students become more aware of contemporary issues in the context of engineering problems. On “project pitch night” representatives from industry, government, non-profit organizations, and faculty provide students with viable projects that they can work on as seniors. All projects are a contemporary issue that can be addressed at least in part with an engineering solution. Typical projects include assistive devices for the physically impaired, alternative energy or energy conservation, transportation, food production, and appropriate design for the third-world.

**ME481/482 Capstone Sequence:** Students select their own projects and discuss the project with the class in terms of its contemporary relevance. This helps students understand the potential impact of their project as well as the projects of their peers and to identify various engineering contemporary issues. Students are required to read at least one article regarding a contemporary engineering issue such as the lack of available drinking water in parts of the world.

**The University Core:** the mechanical engineering students are required to take 27-30 University Core credits. Many social science courses and theology courses discuss contemporary political, social and/or contemporary religious issues.
**Pedagogy for Student Outcome k:** An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Students learn to use modern computer software for solving computational problems, creating engineering drawings, conducting stress analysis, and for data acquisition.

**EGR111 Engineering Computing with Applications:** Students learn basic computer programming using MatLab and apply it to solve engineering problems.

**ME111 Engineering Graphics:** Students learn to use modern computer aided drawing skills (such as SolidWorks).

**ME301 Engineering Analysis:** Students are taught numerical methods for solving engineering problems. Using MatLab they create and apply computer programs throughout this course.

**ME304 Finite Element Analysis:** Students learn about finite element methods and apply finite element analysis and computational fluid dynamics (Autodesk Simulation, Mechanical) to solve strength of materials, fluid flow, heat transfer and modal analysis problems.

**ME351 Mechanical Systems Laboratory:** Students learn to write LabVIEW code and apply it to acquire data. They learn about sensors and data recording systems to solve engineering problems. They learn and apply PID control, PLC, and motion controllers.

**ME336 Heat Transfer:** Students use MatLab and non-linear equation solvers like EES to develop numerical method solutions to solve for unknown temperatures in radiation problems and simple ordinary differential equations. This builds upon the numerical methods skills learned in ME301.

**ME332 Applied Thermodynamics:** Students learn to use EES (Engineering Equation Solver) optimization software for thermal property look up and non-linear equation solving.

**ME376 Thermo Lab:** Students write LabVIEW code and apply it to acquire data. This builds upon the LabVIEW skills learned in ME351.