# A "Portfolio" Approach to Assessing the Industrial Engineering Curriculum at WPI

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## Introduction

One challenge in assessing the outcomes of engineering programs is to develop mechanisms that provide effective measurement and feedback, with reasonable effort. We describe a framework that we are piloting in the Industrial Engineering (IE) program at Worcester Polytechnic Institute (WPI) to evaluate student proficiency with respect to all of our program outcomes.

A number of mechanisms are used for outcomes assessment at WPI, including exit surveys, a peer review of the senior project, and alumni surveys. These mechanisms provide information about the extent to which our graduates meet a particular program outcome, but they do not tell us the extent to which our graduates meet all program outcomes. To develop insight into how completely our students meet program outcomes, we have devised a "portfolio" approach that combines specific course assignments with the senior project review to evaluate individual students across outcomes. We call the resulting collection of materials a portfolio because it ties together the work of individual students[4]. We put the term "portfolio" in quotes because the primary purpose is assessment, rather than self-awareness about learning on the part of the student.

Our "portfolio" approach begins with the collection of assignments in core courses that are required for industrial engineering majors. At WPI, each student also completes a senior design project that is the equivalent of three courses. Because the project is such an extensive and critical part of the WPI curriculum, we have had a peer review system in place for project review for many years. The current "portfolio" approach extends this peer review of senior projects to include the collected course assignments. In addition to meeting course objectives, the assignments typically address outcomes that may not be demonstrated in the senior project, such as an understanding of global issues or ethics. The resulting assessment measures students' achievement of all program outcomes.

## Outcomes Assessment and the IE Program at WPI

As accrediting agencies have pushed toward outcomes assessment, many academic programs have revisited their mission statements and developed assessment mechanisms to demonstrate the accomplishments of their graduates. In particular, ABET has required that engineering programs specify program outcomes, statements that describe what students are expected to know and be able to do by the time of graduation[1]. As part of the accreditation process, programs must evaluate and provide evidence that graduates satisfy these program outcomes. The results of this assessment are then used to make program improvements.

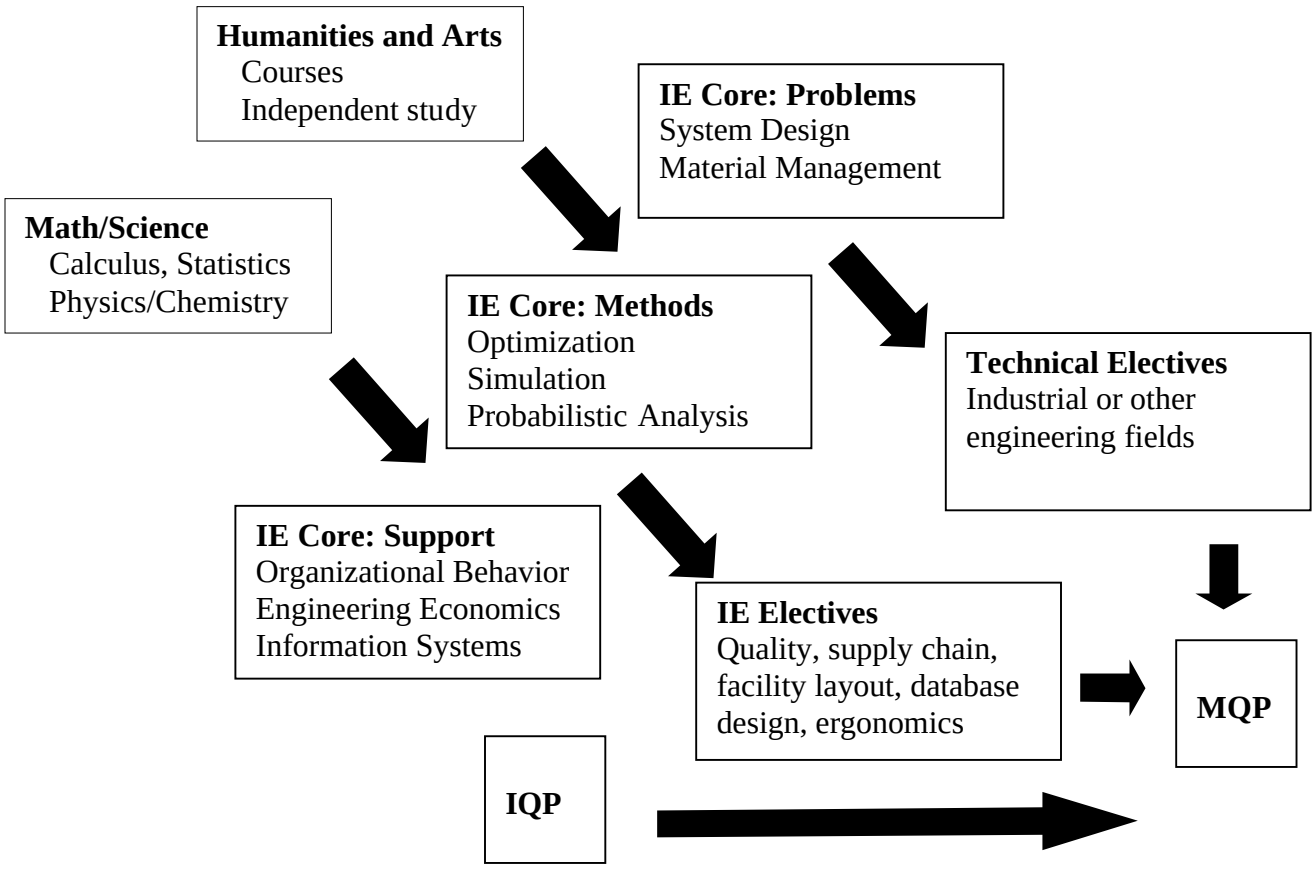


**Figure 1:** Schematic of the IE Curriculum at WPI

The mission statement of the undergraduate Industrial Engineering (IE) program at WPI emphasizes the preparation of undergraduate students for professional engineering practice. In addition to a curriculum focused around core industrial engineering skills, we seek to accomplish the mission through a culture that promotes active student learning. We want to teach the process of learning, rather than simply transferring knowledge to our students. An overview of the IE program is provided in Figure 1; the arrows signify the general order courses are taken. The focus on active learning is reflected in the curriculum by emphasizing project-oriented assignments in courses, as well as promoting flexibility in the curriculum to allow students to pursue minors and choose electives that reflect their interests as well as satisfy program objectives.

Three significant project activities are essential components of the curriculum, which must be completed by every WPI student as part of their degree requirements. By engaging students in the solution of open-ended problems, we strive to teach students problem-solving methods and the skill of learning to learn.

First, in the area of the humanities and arts, students select and take five thematically related courses in an area of interest. This experience culminates in an independent study, where

directed one-on-one by a faculty member, the student produces a critical essay that draws not only on what has been learned in previous work, but explores new territory. The humanities and arts projects sequence is typically completed in the freshman and sophomore years.

The second major project students complete is termed the IQP (which stands for Interactive Qualifying Project), and is the equivalent of three courses. Students select project topics, which must examine how science or technology interacts with societal structures and values, and typically work in a small team (2-4 students) under the direction of a faculty member to complete the project. Many of these projects take place at WPI's Global Project Centers, located around the world. The IQP is most often completed in the junior year.

The final project that a WPI student must complete is a capstone design project in their major, termed the MQP (for Major Qualifying Project), which is typically completed in a student's senior year. The project is equivalent to three courses, and is designed to demonstrate application of disciplinary knowledge and skills in the solution of a problem similar to one that might be encountered early in a student's career. In IE, these projects are almost always sponsored by industry, and students complete the project in teams of 2-4 students, often spending approximately half their time on-site. One result of the senior project is a written report, which details the methodology, analysis, and conclusions of the project. Another result of the project is several oral presentations, typically given at the company site and as part of WPI's Project Presentation Day. On this day, classes are suspended and students from all majors present the results of their projects.

In the context of outcomes assessment, the curriculum represents one means for student development. While means are critical, having a curriculum with the 'right' courses does not ensure that students will be able to apply what they have learned. The end result of a student's education is summarized in the program outcomes, which focus on what a student is able to do at the time of graduation. The program outcomes for the IE program are organized into three categories, as shown in Table 1. To demonstrate that students' achieve program outcomes, these outcomes must be measured. Measurement requires more specificity than the outcome statements; at WPI, most outcomes are further broken down into objectives or attributes[2]. A number of mechanisms are used for measurement, including student and alumni surveys, student course evaluations, and course grades. In addition, the senior capstone design projects are peer-reviewed. Combined, these mechanisms provide several sources of data for measuring the level of achievement of each outcome in Table 1. For example, one might make statements such as "99 percent of graduates are able to communicate effectively at graduation".

In addition to the separate evaluations of each outcome, we would also like to assess how well our students meet all of the program outcomes. For example, we would like to make a statement like "99 percent of the IE Program graduates achieve program outcomes at a satisfactory level". To do this, we needed a different evaluation mechanism. Some existing mechanisms, such as our student exit survey, do address all outcomes; however, they measure student perception rather than seek an objective evaluation of what students are able to accomplish. The peer-review process for the senior capstone project seeks to evaluate the quality of the student work. While such evaluations are not entirely objective, the faculty peer-reviewers have no direct association with the work carried out. While an excellent vehicle for demonstrating what

**Table 1: Program Outcomes for the IE Program at WPI**

| Outcome | Course/Project Used to Evaluate Outcome |
|---|---|
| **Industrial Engineering Knowledge and Design Skills** | |
| **(a)** An ability to identify, formulate, and solve industrial engineering problems. | Senior Design Project<br>Linear Programming |
| **(b)** An ability to design and conduct experiments, as well as to analyze and interpret data. | Quality Control<br>Simulation |
| **(c)** An ability to design and improve integrated systems of people, materials, information, facilities and technology. | Senior Design Project<br>Engineering Economics |
| **(d)** An ability to apply core industrial engineering concepts, using the updated techniques, skills and tools necessary for industrial engineering practice. | Senior Design Project |
| **(e)** The broad education necessary to understand the impact of engineering solutions in a societal context. | Senior Design Project<br>IQP |
| **(f)** An ability to apply knowledge of mathematics, including statistics as well as integral and differential calculus. | Production Planning and Control |
| **(g)** An understanding of fundamental physical laws. | Production Planning and Control |
| **Communication Skills** | |
| **(h)** An ability to communicate effectively. | Senior Design Project |
| **Teamwork and Leadership Skills** | |
| **(i)** An ability to work effectively on multi-disciplinary teams. | Senior Design Project |
| **(j)** An understanding of professional and ethical responsibility. | Senior Design Project |
| **(k)** A recognition of the need for and an ability to engage in life-long learning. | Senior Design Project |
| **(l)** A knowledge of contemporary issues. | Production System Design |
| **(m)** An understanding of global issues. | Production System Design |
| **(n)** An understanding of change management in organizational settings. | Senior Design Project<br>Organizational Behavior |

students can do, most senior capstone projects do not address all program outcomes. The "portfolio" evaluation we describe below extends the peer-review process in place for senior capstone design projects, to provide a holistic view of the program outcomes for assessment.

## A "Portfolio" Approach

As many assessment experts have noted[2,5], choosing which outcomes (or objectives/attributes) to measure and how is a critical step to ensure both important results and a reasonble data collection effort. To gain insight into the strengths of our students across program outcomes, we needed a mechanism for evaluating those outcomes that were not always part of the senior capstone design project. We also wanted to develop an approach that seemed reasonable in terms of faculty

effort. The IE program at WPI is small, with five full-time faculty members who deliver the bulk of the program. The process we developed results in a "portfolio" for each student, collecting work from particular courses and combining it with the capstone design project results. The major stages in the process are described below, and broadly follow the steps described by other authors for developing assessment plans[3].

### *Stage 1: Design*

In the first stage of the process, the "portfolio" is broadly defined by mapping the program outcomes to curriculum elements to determine where each will be measured. We have evaluated the senior capstone design projects over a period of 10 years, and from these evaluations, know which outcomes are demonstrated in these projects. For example, because every project requires an extensive written report as well as oral presentations, all capstone projects allow us to evaluate student proficiency related to communication. Such projects also provide students with insight on contemporary issues in organizations, particularly related to industrial engineering and change. Combined with the IQP, the senior design project gives students opportunities to learn effective teamwork and project/time management skills. On the other hand, only some projects address global issues and an ability to design and conduct experiments.

We mapped the outcomes that were not always addressed in the capstone design projects to seven courses required of all IE graduates, as shown in Table 1. For example, we mapped outcome (m), "an understanding of global issues" into the introductory IE course, entitled Production System Design. In this course, students are introduced to process analysis and measurement (e.g., lead time), total quality management, layout, and materials management. We wanted students to also understand these IE problems in the context of a global organization. We mapped outcome a, "an ability to identify, formulate, and solve industrial engineering problems', into our linear programming course. While all senior projects involve the identification and solution of IE problems, the formulation step is not always a formal model. In this case, we mapped only an objective related to modeling into the course.

### *Stage 2: Data Collection*

After we completed the mapping, the second stage was to begin collection of "portfolio" assignments. Given the outcome(s) assigned to a course, the faculty member teaching the course selected an assignment that could be used to demonstrate proficiency in the outcome. These assignments are typically course projects, not developed specifically for the portfolio but rather to meet course objectives. The assignments are graded within the context of the course, and the students receive this feedback. The assignments are also copied and placed in each student's portfolio file. To support accreditation, the IE faculty regularly collect assignments for course notebooks, so the collection process was not viewed as substantially different from this effort.

Because the assignments are developed for the course and chosen by the faculty member, they may change from year to year. The full-time faculty are knowledgeable about outcomes assessment and familiar with the program outcomes; choosing assignments has not been difficult. We have not yet had adjunct faculty teach a required course from which we are

collecting "portfolio" assignments. Because the person teaching the course does not evaluate proficiency related to the outcome, the important message to be conveyed to the adjunct is the need to identify an assignment related to the outcome and the need to collect copies of the assignment.

***Stage 3: Evaluation***

The third step in the "portfolio" process is the evaluation of the materials that have been collected. We are in the process of this evaluation stage, although it is currently incomplete. We began piloting the process in January 2001, but because students often begin taking required IE course in their sophomore year, assembling a complete portfolio takes several years.

Senior capstone design projects are reviewed annually, usually during the summer following the academic year. Each IE design project is assigned to two faculty members for review (neither is the project advisor); this allows us to develop some measure of reviewer consistency. Each year, approximately 6-8 senior projects are completed, so each faculty member has approximately 3 projects to review. Generally, each faculty member is provided with a small stipend based on the number of projects reviewed. The reviewers are provided with a form on which to score the project across a range of outcomes. In addition to the project report (which has formed the basis for the review in the past), we are developing survey instruments for students, faculty advisors, and project sponsors to more specifically evaluate teamwork and communication.

In our "portfolio" framework, this senior capstone design evaluation is extended to include the portfolio assignments as well. Thus, in addition to the MQP, a faculty reviewer will receive the assignments of the students who completed the projects they review (approximately 5-6 students) The entire "portfolio" then represents a sample of each student's work that crosses all outcomes. Because we are starting small, evaluating a few chosen outcomes in selected courses and building on an existing process, the faculty feel the overall effort is not overwhelming.

For each assignment and outcomes, rubrics have been or are being developed to assist in consistent evaluation. Such scoring criteria are used to evaluate the quality of the work, by defining specific dimensions of the outcome and developing a rating scheme for each dimension with specific performance criteria[6]. For example, in the context of outcome (m), an understanding of global issues, we determined that there were three dimensions that defined this outcome for the introductory course:

- Students know about specific companies with global operations (demonstrating knowledge of current events);
- Students understand the impact of global operations on an aspect of operations design, such as product design or inventory management;
- Students understand specific elements of globalization (e.g, cultural, currency, regulations) that add complexity to operations.

For each of these dimensions, we use a simple evaluation scale to rate projects. The evaluation scale is tied to specific performance objectives:

- Exceeds expectations – students provide examples and explain the examples given
- Meets expectations – students can provide specific examples
- Needs improvement – students cannot provide specific examples.

The evaluation process is designed to yield information about students' proficiency as a group, rather than on an individual basis. The "portfolio" of each student will be evaluated only after a student has graduated. The resulting evaluations will yield an understanding of the breadth of our graduates' skills. Unlike more traditional portfolios[5], we are not using our "portfolios" to provide students with feedback about their level of achievement on particular outcomes as a means to improve their learning. Students are also not asked to choose their best work as a showcase for their abilities. We plan to use our "portfolios" solely as a program assessment tool, although they may evolve into a learning tool over time.

***Stage 4: Improvement***

The final stage of our "portfolio" approach will be to use the results and experience from each annual assessment to improve the process. As the rubrics used to score student work are utilized, some will likely need to be clarified or enhanced. In addition, as we gain experience with the process or as program outcomes change, we expect to add additional assignments to the "portfolio" (and perhaps eliminate some). The "portfolio" assignments can also be built around other program objectives. We often seek to build depth in the curriculum by introducing a topic or experience in one course and then building on it in later courses. As an example, projects are used frequently within courses, building a 'way of thinking' that we presume helps students with the IQP and senior design project. We could develop rubrics that would allow us to evaluate the depth of student's project skills in their coursework and in their three-course projects, and evaluate growth in project skills as part of the "portfolio" assessment.

## Conclusion

In this paper, we describe an approach for creating student "portfolios" that can be used to assess the extent to which graduates of the IE program at WPI satisfy all program outcomes. Major factors in designing the process include effectiveness, faculty effort, and building on current assessment approaches. To ensure effectiveness yet limit the scope and effort required in the evaluation, we utilized data from the peer-review process of senior capstone design projects to identify outcomes that were not sufficiently represented in the design project. For these outcomes, we identified specific courses that could be used to provide evidence about the quality of student work related to the outcome. The process used to collect assignments and evaluate them builds on existing activities, which the faculty have participated in for at least several years. In addition to providing feedback about program outcomes, we expect the "portfolio" process to provide a foundation for collecting information about our courses and the links between them.

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