Integration and Synthesis of the Industrial Engineering Curriculum via an Unstructured Problem Solving Course

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Abstract

The Department of Industrial Engineering at the University of Pittsburgh is addressing an important issue – how to develop a comprehensive, integrated curriculum that (1) is pedagogically sound, (2) thoroughly prepares graduating engineering students for industrial practice and graduate school, and (3) trains students to readily recognize and apply their engineering background to solve unstructured problems, both locally and beyond US borders. Beginning in September 2003 we embarked on an innovative approach to curriculum reform that contains four overarching objectives, namely (1) the integration of concepts across the curriculum; (2) teaching students to synthesize different concepts to solve unstructured problems; (3) providing problem solving methods and strategies within a societal framework that allows for their application within a local as well as a global context; and (4) creating a portable development methodology that can be readily adapted to other engineering disciplines. This paper reports on the development and implementation of a new course IE 1091 - Unstructured Problem Solving that was piloted in the Summer 2004 Semester. Faculty and student assessment of the course are reported and analyzed at three distinct periods – during the course, immediately upon completion of the course, and six months after completion of the course.

1. Introduction

We address a pressing issue in engineering education – how to develop a comprehensive, integrated industrial engineering curriculum that thoroughly prepares graduates not only for industrial practice or graduate school, but also trains students to readily recognize and apply their engineering background to solve problems, both locally and internationally. At the 2004 ASEE Annual Conference, the authors discussed how we are revising the undergraduate IE curriculum at the University of Pittsburgh with four primary objectives in mind:

1. Integration: Integrate concepts across the curriculum via
   - Reinforcement of course material throughout the curriculum.
   - "Just-in-time" concept integration.

2. Synthesis: Teach students how to synthesize different concepts to solve problems.
   - Industrial engineers often face ill-defined, complex problems in systems where there are significant interactions between different sub-system components.
   - Students often fail to see that solving a problem in practice requires the application of several different IE concepts and methods, and that the essence of
IE lies in the ability to successfully integrate these methods within a system-level approach.

3. **Localization/Globalization**: Provide problem solving methods and strategies for problems within a local context and then extend them to a global context, where we also consider various societal impacts.

4. **Portability**: Create a framework for course integration, synthesis, and an appreciation for local and global issues that will be directly applicable to other IE programs, with the capability for adaptation by other fields of study.

The authors also presented a conceptual model for integrating and synthesizing the industrial engineering curriculum. We began by identifying the core knowledge areas of IE and the expected life-long engineering proficiencies. We then developed a plan that builds on and continually reinforces these areas throughout the curriculum in support of our first objective of integration. Following this we detailed a plan for combining the technical skills with life-long engineering proficiencies, in support of our second objective of synthesis. Finally, we discussed curricular implications of the changing role of science and technology in society. Pedagogical issues related to each of these steps were also presented and discussed. The conceptual model that we proposed is shown in Figure 1.

![Figure 1. Conceptual Model for Curriculum Integration & Synthesis](image-url)

This paper extends the work reported in the previous paper and reports on the development and implementation of a new course entitled **IE 1091 – Unstructured Problem Solving** that was
piloted in the Summer 2004 Semester. This new course was one of the pedagogical tools
developed to specifically address three of our primary objectives, namely: integration, synthesis,
and localization/globalization. In the remaining portion of the paper, we provide a detailed
description of the course and describe our numerous assessment methods. Faculty and student
assessment of the course are reported and analyzed at three distinct periods – during the course,
immediately upon completion of the course, and six months after completion of the course. We
conclude with a discussion of lessons learned and future plans for offering this course.

2. Course Description and Pedagogy

We developed and taught IE 1091 – Unstructured Problem Solving over the 12-week summer
term of 2004. This course was aimed primarily at undergraduate students who had already
completed a fairly substantial amount of coursework in industrial engineering – most of the
students who registered for the class had between one and two additional terms of classes left
after the summer term, before they could graduate. In this section we provide details about our
objectives for the class, the course content, and the pedagogy that was followed.

The objective of IE 1091 was to teach students how to go about systematically solving a
relatively complex, unstructured, and ill-defined problem. The course placed emphasis on
several aspects including (1) the integrative use of a variety of industrial engineering techniques
that students had already learned in prior classes, (2) the consideration of qualitative factors and
a broader global/societal context, (3) the use of teams to solve problems, and (4) effective oral
and written communication of technical results. The pedagogy for the course revolved around a
team-taught, project-based approach that stressed attendance and class participation. The class
consisted of 12 students who were divided into three 4-person teams. There were two class
sessions each week and each session ran for an hour and forty five minutes. Final course
deliverables consisted of both individual and team writing assignments and culminated with a
final group report and presentation.

At the heart of the course were two separate projects/cases, each involving a different fictitious
company. We spent half the term (6 weeks / 12 class sessions) on each of these. Each of the
three student teams was required to individually work on both cases. While the actual problems
and the data in the cases were generated by the instructors, they were both loosely based on two
actual companies that one or more of us had worked with. The first case (Giovanni’s Bakery)
was based on a small company that bakes and delivers a variety of breads to a number of local
restaurants, grocery stores, and individual customers. The second case (Wireplastics, plc) was
based on a unit of a multinational that is based in the Pittsburgh area and supplies customers
around the world. A brief synopsis of each case is given below:

Giovanni’s Bakery: Giovanni’s Bakery is a family run business currently being run by the
granddaughter of the original founder and employs 29 people including management, staff,
bakers and truck drivers. It operates seven days a week in a union environment. Giovanni’s has
over $3 million in sales every year, and produces over 70 different products, serving about 450
commercial customers. Types of products include breads, rolls, buns, and specialty breads and
while its customer base is mostly in one county the company also serves four other neighboring
counties. The bakery has operated much the same as it did since its inception. Its facility is
rather old and the operations have evolved over time as opposed to having grown through a well thought out design. The facility and its layout are not optimal for mass production. Recently, Giovanni’s is facing stiff competition from larger, more modern bakeries. Some of the symptoms that they have been experiencing include extensive overtime, late deliveries, shortages, space/capacity constraints, a drastic variation in product quality, and costly relay deliveries made daily to make up for these occurrences. The goal of the project team is to help Giovanni’s improve their operations, eliminate operational inefficiencies, and position them better for future growth.

**Wireplastics, plc**: Wireplastics is a global company quoted on the London Stock Exchange with sales of approximately $200 million and 2,300 employees in the fields of technical plastic, which contributes about 77% of sales and specialist wire products, which contributes the other 23%. The plastics side of the business was the focus of this project; it is a truly global manufacturing operation with seven locations in the US, 6 in the United Kingdom, 1 in the Czech Republic, and one in the Peoples Republic of China. The project team was asked to focus on three separate issues about which people at various levels in Wireplastics are becoming concerned. The first is an operational one involving a potential quality problem with plastic welds at a specific plant operated by Wireplastics. The second issue is more of a tactical one involving production and inventory control that the company would like to explore at the same plant with the idea of incorporating solutions or successful approaches to other operating units as well. The last issue is mostly a strategic one related to Wireplastics’ supply chain and the distribution scheme at its subsidiaries around the globe; a related issue is possible outsourcing of some production to China, either by adding capacity at the existing plant or by opening up a newer facility.

In order to give each case a different flavor of localization/globalization, we purposely developed one that was based on a small, local, “mom-and-pop” company, while the other case was based on a large multinational corporation with a global customer base and supply chain. We used the actual data that we had obtained from each of these companies as a starting point, but this was then adapted and drastically expanded to be relevant to the issues that we were introducing in each of the cases. In generating this data and the issues that are alluded to in the synopses above, our objective was to force the students to identify, integrate and employ many different tools and techniques that they had learned earlier in their program. Thus, each case had to be made up in such a way that it allowed for the potential use of these tools. Some of the actual techniques that the students used on one or both cases included facility layout, flow-charting, product flow analysis, forecasting, statistical analysis, inventory control, linear programming, database design, regression analysis and statistical quality control.

There were four faculty members who taught the course with two taking primary responsibility for the Giovanni’s case and the other two for the Wireplastics case. However, in many of the class sessions the secondary faculty members would still sit in and offer suggestions and comments. Each actual class session comprised a combination (in varying amounts) of presentations, question-and-answer, role-playing and lecture. We would start by presenting information about the company and problems it was facing in order to elicit questions from the students. This would lead to a question-and-answer session where the faculty would play the role of company employees and the student teams would ask questions with the idea of identifying possible ways to address specific problems and the associated information.
requirements. Each company had “employees” with specific job responsibilities relevant to the project – the student teams were provided with backgrounds on each employee and one of the faculty members would play the role of an employee; the teams were expected to direct questions for data and/or information to the appropriate employee. Data would be given out gradually, and only to the extent of what the students asked for. If the data was not available the students had to think of alternative approaches. On occasion the data given out would be incomplete or partially incorrect and the teams were expected to make intelligent assumptions to deal with these situations. Given the available information and background, the teams were expected to identify appropriate methods to attack the specific problem under consideration. In some instances where students had not yet learned certain techniques brief lectures were provided in those topics. Finally, considerable emphasis was placed on qualitative/subjective/human issues which cannot always be modeled or quantitatively analyzed. Many of these related to the impact of decisions and recommendations on a local, societal or global level.

To monitor the progress of the project and to ensure that the teams stayed on track there were two interim status reports, the first after two weeks and the second after four weeks. In each of these sessions the student teams had to make a 10-minute presentation on what they had done thus far and what they planned to do over the next two weeks. In addition, they had to provide brief, written progress reports. An interesting aspect of the class was that while the teams often came up with similar ideas, there were other occasions when a team had a unique idea, which would then be adopted by the other teams. At the end of six weeks, each team was required to make a detailed 20-minute presentation to management that summarized their work and provided recommendations. In addition, each team also had to turn in a detailed, written project report with supporting data and analysis. Each project accounted for 50% of the student’s final grade and in order to ensure individual accountability, 40% came from the work done by the team as a whole and 10% was based on the individual team member’s contributions. In grading their work, emphasis was placed on how well the students had integrated various approaches to solve the problems at hand, as well as on the level of rigor in their analysis and solution procedures. In the following section we provide details on the assessment procedures followed (for students as well as the course and faculty), followed by some of the lessons learned.

3. Assessment and Evaluation

The assessment techniques discussed here relate to the second and third pedagogical objectives of our curriculum grant – “teach students how to synthesize different concepts to solve problems”; and “provide problem solving methods and strategies for problems within a local context and extend them to permit students to apply them within a global context where we also consider various societal impacts.” In implementing the new problem solving course, we had three overarching evaluation questions that we wanted to address:

- *Are students able to synthesize and integrate concepts learned in prior courses?*
- *Are students equipped with problem solving methods/strategies prior to their senior capstone project?*
- *Do graduates appreciate the societal role of industrial engineering, both locally as well as globally?*

In addressing these questions, the assessment of the course and students consisted of multiple qualitative and quantitative methods, such as student feedback surveys, question generation, oral
presentations, written reports, multi-source feedback, ABET evaluations, concept maps and focus groups. These methods focused on both formative and summative evaluation. The assessment provided in this paper is divided into the assessment of students and of the course.

3.1 Assessment of Students

During the course several assessment methods were employed to evaluate the students’ performance in the class as well as the overarching objectives of the grant. From a formative perspective, question generation, “typical” course homework, as well as periodic status reports were employed to obtain feedback during the semester on the students’ performance. The question generation proved to be a useful formative method for verifying how students were thinking about the open-ended problems and approaching potential solutions. Student teams submitted questions on a weekly basis to the instructors, who in turn addressed the questions in class and provided problem solving tips and possible avenues for the student groups to pursue. In addition, students were periodically assigned both individual and group homework on various IE techniques that were needed for the particular problem. For example, before students developed control charts for the Wireplastics case, they first demonstrated the ability to develop control charts on sample “canned” book problems. Finally, the student teams prepared a short oral status report on their project and presented it to the entire class. This afforded the instructors and students opportunities to evaluate how the team was progressing towards a solution and to offer additional suggestions.

From a summative standpoint, the students’ performance in the class was based on four primary assessments: oral presentation, written presentation, multi-source feedback on teamwork abilities, and perceived course integration. At the end of each problem, the student teams presented their findings, results and recommendations in an oral presentation as well as a written report. Both the oral presentations and written reports were graded by each instructor in the course using rubrics developed for each. In addition, for each project the students rated themselves and their team members on their teamwork capabilities through a two-page questionnaire. Because the course was primarily graded based on team collaboration, it was important for the students to reflect through open-ended questions and along seven different dimensions of team contribution (i.e. attendance, preparation, contribution, work load, timeliness, organization and attitude). In general, the team members contributed well. There were a few instances in which some members felt that other team members did not equally contribute on one or more dimensions.

To directly address how students were able to better synthesize skills developed from multiple courses to solve new problems, the students were asked to give their perspective on how they were able to integrate the various concepts and skills acquired from other courses. This was accomplished by asking the students to consider how much they made use of the concepts, principles or methods that were covered in the various industrial engineering courses that they had previously taken. Students rated each course with “considerable use,” “some use,” or “minimal or no use” (students also indicated if they had not taken the course).
3.2 Assessment of the Course

To assess the course from a formative perspective, feedback surveys were delivered to the students three times during the semester. The first survey was given towards the end of the first project. Here the students were asked to evaluate both the level of work required as compared to other courses as well as the instructors involved in the particular project. Students were concerned about the amount of time involved and felt very unsure about the open-ended nature of the problem. In addition, the students were concerned about the grading mechanism that was being employed (i.e., based heavily on two team-based written reports). Such responses are typical for new courses. The instructors did make adjustments for the work load when conducting the second project. The other two surveys were given at upon completion of each project. These surveys addressed how worthwhile the project was and what the students gained from the project. Students were also asked to provide suggestions on how to improve the course in the future. In addition to the surveys, students rated the course with regard to the ABET outcomes. Here we were particularly interested in how the course improved students’ abilities along four ABET outcomes: (b) an ability to design and conduct experiments, as well as to analyze and interpret data, (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, (e) an ability to identify, formulate, and solve engineering problems, and (g) an ability to communicate effectively.

To directly address how students were able to better synthesize skills developed from multiple courses to new problems, concept maps\(^2\) are being employed as a direct measure of the students’ ability to better integrate concepts, principles and methods. The Industrial Engineering Department routinely assesses graduating senior students using concept maps and a scoring rubric to investigate anticipated gains in comprehension, organization, and correctness from previous cohorts of students. The students who participated in the course are now seniors and will be developing concept maps of Industrial Engineering. These maps will be compared with a comparison group of seniors (i.e., similar in terms of GPA and work experience) to determine if there are substantial differences in the rubric scores.

To address how students appreciate the role that the industrial engineering field plays both locally and globally, focus groups, one consisting of only participants from the class and one consisting of a comparison group who did not participate in the course are being conducted during the Spring 2005 Semester. The focus group questions are attentive to both the reflection of the course but also to how students perceive the field of IE in the world. It is anticipated that the responses will be more rich and reflective for those students who participated in the course.

4. Lessons Learned and Future Plans

We learned that the course was a great experience for the students, although some did not admit this until several weeks after the course had concluded and the “pain” had subsided. The course was offered in the summer and was taken primarily by our students who were back in school from their co-op rotations. These tended to be some of our better and more experienced students. They remarked that the course would have been difficult to take during a regular fall or spring
semester when students would typically be taking a full load of (five) courses. Most of the students in the Summer 2004 term were taking only four classes. These remarks were troubling because we feel that the course would be most beneficial to the students who had not previously co-oped or interned, as it would provide them valuable experience that would be useful for their senior design project.

Initially when we developed this course, our plans were to first pilot it as a technical elective with a small, select group of students. Eventually, the course would then be required to be taken by the entire IE student body in their junior year in preparation for their Senior Design Project. After piloting the course for the first time, we concluded that the course was very demanding on both the students and the faculty. Furthermore, it would be very challenging to offer the course in a large setting to say 40-60 students (or 10-15 teams). We therefore are proceeding cautiously with our plans to offer this course to all of the IE students in either the fall or spring semester.

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6. References


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