An Evaluation of Introduction to Industrial Engineering Course at Sabancı University Using CIPP Model

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Abstract

Identifying course objectives in accordance with the needs and expectations of students and industry with a focus on both efficiency and sustainability has been a challenge for engineering programs. The gravity of this complicated issue arises in designing the introductory courses to familiarize students with the profession as well as introducing the content of the successive years. Within this respect, we conducted an evaluation project at Sabancı University on the curriculum of an introductory course in industrial engineering. This study reports the findings obtained on content organization and alignment of learning outcomes with the main goals of the course. We adopted convergent parallel mixed method in which quantitative and qualitative data are collected and analyzed separately through content analysis and descriptive statistics (Creswell, 2014). We collected data from multiple qualitative (i.e., semi-structured interviews and document analysis) and quantitative sources (i.e., surveys and objectives alignment scale). Our results suggest that this introductory level course comprises rather theoretical and complicated subjects. Agreeing upon the complexity of the course content and incongruence of learning outcomes with the course goals, the lecturers recommended introducing more conceptual but less methodological topics.

1 Introduction

Bridging the gap between engineering curricula and industry needs and expectations has been an ongoing effort to raise more skilled engineering graduates which is otherwise underlined to pose a real threat to the competitiveness in the global market (Lang, Cruse, McVey & McMasters, 1999). In addition, challenges with incorporating the notion of sustainable development and aspects of sustainable engineering into higher education have been forthcoming more recently (Allenby, Murphy, Allen & Davidson, 2009; Segalàs, Ferrer-Balas, Svanström, Lundqvist & Mudler, 2009). Adopting a learner-centered, liberal education approach, which aims to facilitate the needs and desires of the learner to become a fulfilled individual (Cronon, 1998; Ellis, 2013), Sabancı University in Turkey intends to equip students with a broad knowledge of science, literature, history, mathematics and the arts. The Industrial Engineering (IE) is the largest diploma program declared by almost 700 students as their majors at the end of their Foundation Development Program (i.e., freshman year) as of 2016-2017 academic year. Equipping students with essential skills in congruence with the requirement of the profession to become problem solvers, entrepreneurs, advocates of sustainability, and change agents within the society constitutes the major aims of the IE program.

Traditionally, the profession of industrial engineering with a system-wide focus is engaged with designing and planning parts of systems to produce results in an optimal manner, concerned mainly with efficiency by reducing the consumption of resources. Considering the technological developments and environmental issues, this perspective should be expanded with the aim of reducing the hazardous impacts on resources as well. Falling behind the technological developments, needs of the society and demands of the market, the IE curricula are undergoing a revision process with redesigning the three fundamental courses which are offered consecutively and built conceptually upon each other: ENS 208 Introduction to Industrial Engineering, IE 301 Deterministic Models in Operations Research and IE 302 Stochastic Models in Operations Research. ENS 208 is the first course of this chain and aims to introduce the industrial engineering field as well as laying the foundation of the successive courses. A course evaluation which provides information on program adoption, continuation or expansion was conducted in ENS 208 in Spring 2017 semester to help decision makers in forming judgments on necessary aspects for revision (Fitzpatrick et al., 2004). As a part of that evaluation project, this study focuses on content organization of ENS 208 and aims to shed light on following research questions:

1) Are learning outcomes and content organization of ENS 208 aligned with the main goal of the course?
2) Can students establish the relationship among content units at the end of semester?

1.1 Origin of the ENS 208 Introduction to Industrial Engineering Curriculum

ENS 208 Introduction to Industrial Engineering is a sophomore level first course in the IE program. As an introductory course, it is open to all students at the university; students may take this course either before or after they declare their majors. Upon completing ENS 208, sophomore students can decide to go on studying in Industrial Engineering or declare another major. Therefore, such a course might be a milestone for students in choosing their majors. Every regular semester, more than 200 students who would like to be acquainted with industrial engineering profession take this course.

The curriculum development process has been carried out as compilation of some related topics from a textbook and sequencing them in line with the goal of the course. The content is broken down into discrete subjects and planned in advance by the instructor(s) according to the textbook. Criticizing the adoption of course books as curriculum, Ellis (2013) states that this approach ignores the expressed learner interest despite the fact that it provides structure in the form of scope and sequence while ensuring equal access to knowledge and providing each student with the basic knowledge s/he needs.

1.2 Characteristics of Introduction to Industrial Engineering

With three lecture hours and one-hour recitation a week for 14 weeks, ENS 208 is studied at a very elementary level to teach fundamental notions and represent the course work in the later years of the program. The course content has been organized thematically around three major themes regarded as the most traditional and fundamental areas in industrial engineering:

- Deterministic models in operations research
- Operations in production and service systems
- Production and service systems planning problems

The main goal of ENS 208 is to familiarize students with the Industrial Engineering profession by introducing the content of the junior and senior year courses delivered later in the program. Table 1 illustrates the current learning outcomes of the course as planned. Each outcome encompasses skills in cognitive domain according to Bloom’s taxonomy that is a framework to organize educational objectives and explains the levels of expertise to achieve each measurable students’ outcome (Bloom et al., 1956).

Table 6: ENS 208 Current Learning Outcomes and Corresponding Cognitive Level

Learning Outcomes	Cognitive Level
To be familiar with and utilize the most important methods for forecasting demand.	Remember /Apply
To develop aggregate production plans.	Create
To model and solve linear programming problems	Apply / Create
To use graphical solution technique	Apply
To perform sensitivity analysis.	Apply
To model and solve transportation, assignment, fixed-charged, and knapsack type of problems.	Apply / Create
To be familiarize with basic concepts in deterministic inventory management and control individual item inventories.	Understand
To gain an understanding of the key methods for shop scheduling and assembly line balancing.	Understand
To utilize mathematical and graphical techniques for project scheduling.	Apply

Organizing the course outcomes regarding the can-do statements in the taxonomy allows the practitioners to choose appropriate techniques for the course. Figure 1 summarizes the cognitive levels in Bloom's revised taxonomy and what students are expected to perform as they proceed from low-levels of thinking to higher.

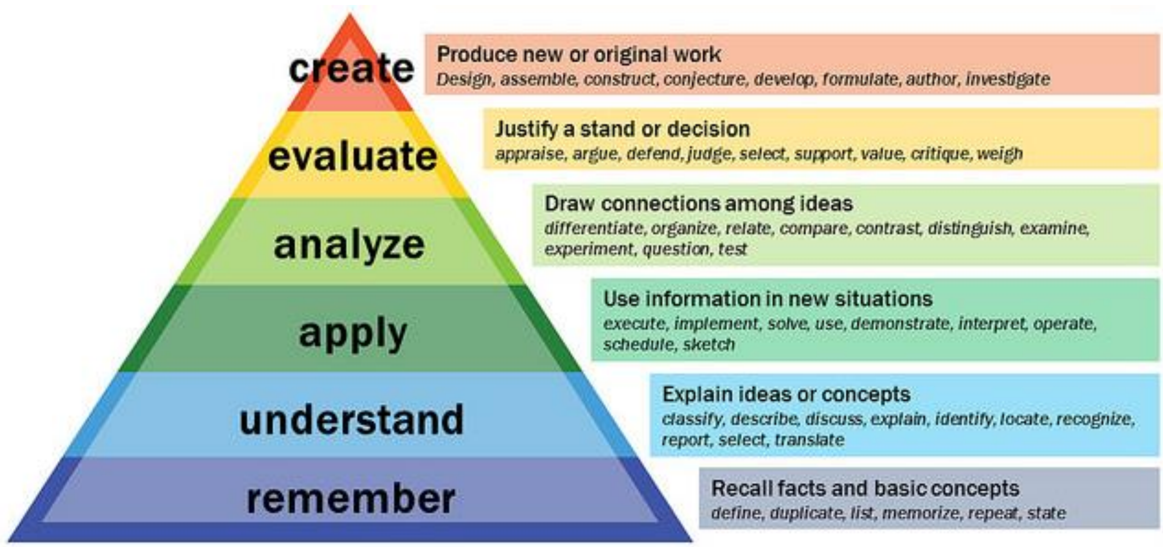

Figure 10: Bloom's Revised Taxonomy (Vanderbilt University Center for Teaching)

2 Method

2.1 Research Design

The evaluation study adopted convergent parallel mixed method in which quantitative and qualitative data are collected and analyzed separately (Creswell, 2014). We collected data from multiple qualitative and quantitative sources separately and combined their results in the final stage to reveal whether the findings would confirm or disconfirm each other. Within mixed method designs, we utilized partially mixed concurrent equal status design with two concurrent phases by giving equal weight to quantitative and qualitative data (Leech & Onwuegbuzie, 2007).

2.2 Evaluation Model

The complete evaluation project was planned to adopt the CIPP evaluation model (Context, Input, Process and Product) which is a management-oriented approach and regards the evaluative information as a crucial part of good decision making (Fitzpatrick et al., 2004; Stufflebeam, 1971). This part of the study discusses the findings obtained from only two phases: *Input* phase to identify and assess system capabilities including alternative program strategies, and *Product* phase to gather data about the outcomes of the program and relate them to objectives (Fitzpatrick et al., 2004; Stufflebeam, 1971). Whereas the Input phase was employed to seek answers on the alignment of ENS 208 learning outcomes and content organization with the main goal of the course, Product phase aimed to reveal the extent students can establish the relationships among units at the end of semester.

2.3 Data Sources, Participants and Instruments

Data were collected through the following sources to triangulate the findings and gather multiple perspectives:

- Course outline, learning outcomes and goals was examined.
- To investigate the alignment of current ENS 208 learning outcomes with the course main goals, a survey was administered to all lecturers in the IE program (*N*=15). Participants rated the relationship of each outcome with the main goals on a 4-point scale ranging from *1=None* to *4=High* relation. They were also asked three open-ended questions to reveal any irrelevant learning outcomes and to suggest new ones.
- Two distinct surveys including items on course outcomes were administered to current ENS 208 students (*n*=79) and senior IE students (*n*=66) through a Likert type scale.
- Individual semi-structured interviews were conducted with current ENS 208 students (*n*=8) asking questions on course organization and outcomes. Interviewees were selected based on their GPA scores with criterion sampling method.

The face validity of all instruments (appropriateness, clarity and wording of the items) was scrutinized by an expert in the field of Curriculum and Instruction, a subject-matter specialist and five Ph.D. students.

2.4 Analysis

The document analysis was conducted with the subject matter specialist to check the internal consistency of the curriculum. Quantitative data including lecturers' outcomes alignment scale and the results of current and senior students' questionnaires were analyzed by descriptive statistics using SPSS 23.0. Qualitative data consisting of interview results and open-ended items in the questionnaires were analyzed by a content analysis procedure using descriptive coding that helps categorize and index the data for further analytic work (Saldaña, 2011).

3 Results

Regarding the main goal of the course as familiarizing students with the IE profession and the content of the successive courses, we endeavoured to find clear-cut answers about the students' and lecturers' expectations from an introductory course content in a program adopting the liberal education approach.

3.1 Are current learning outcomes and content organization of ENS 208 aligned with the main goal of the course?

The lecturers in the program rated only one outcome of the course as highly related to the main goals of the course (60.2%) which is formulated as modelling and solving linear programming problems (*Outcome 3).* Three outcomes were considered to have low relationship with the goals (*Outcomes 5, 6, and 8)*; five of them were regarded to have medium relationship (*Outcomes 1, 2, 4, 7, and 9).*

Emphasizing the complexity of the content, the lecturers underlined that current course organization should be modified to include more generic topics. Some of the lecturers marked that:

> *(Lecturer A) I think that these outcomes are not sufficient. There are some other basic IE concepts which are more conceptual and less methodological. For example, the students could get familiar with modelling a system (without technical details); like drawing a flowchart to see the big picture of a system.*
>
> *(Lecturer B) We are pushing too much to teach several subjects. Instead, we need to focus on the general ideas in industrial engineering. I value two things very much:*
>
> > *1) Modelling of various deterministic and stochastic models in inventory management, transportation and scheduling.*
> >
> > *2) Preparing students for computational thinking with a tool like Python or Matlab, where students need to go through the basics of optimization and simulation.*

Table 7: Learning Outcomes Alignment Scale Results

ENS 208 Learning Outcomes Alignment Scale	None	Low	Medium	High
1. To be familiar with and utilize the most important methods for forecasting demand.	7.7 %	30.8%	46.2%	15.4%
2. To develop aggregate production plans.	15.4%	30.8%	38.5%	15.4%
3. To model and solve linear programming problems	-------	-------	30.8%	60.2%
4. To use graphical solution technique	7.7%	15.4%	53.8%	23.1%
5. To perform sensitivity analysis.	15.4%	38.5%	30.8%	15.4%
6. To model and solve transportation, assignment, fixed-charged, and knapsack type of problems	-------	38.5%	30.8%	30.8%
7. To be familiar with basic concepts in deterministic inventory management and control individual item inventories.	7.7%	15.4%	46.2%	30.8%
8. To gain an understanding of the key methods for shop scheduling and assembly line balancing.	7.7%	53.8%	23.1%	15.4%
9. To utilize mathematical and graphical techniques for project scheduling.	7.7%	38.5%	38.5%	15.4%

Though the lecturers consider most of the outcomes not aligned with the main goals, both current and senior students agree that the course enabled them to gain an insight about the IE profession to some extent, and they became familiar with the content of successive courses (*M* scores range from 3.50 to

4.11) [5]. A senior student emphasized how this course led him/her to choose the IE program and helped him/her to understand the content of the successive courses:

> *(Student C) From the very beginning of the course, we were informed about the various fields where an industrial engineer can work. Besides, our lecturer invited a couple of foreign and Turkish industrial engineers as guests to introduce their projects which encouraged me to work in this field. (…) It is a very crucial course as it lays the foundation of the successive courses. I think students experiencing difficulty in this course should not choose the IE program. In this respect, it is a very useful course.*

Despite the fact that both students and lecturers agree on the achievement of ENS 208 introducing the IE profession, they also assert that the course is comprised of too many topics to cover. In this context, senior students partially agree on the statement that the content of the course is appropriate for sophomore students (*M* =3.70*, SD* = 1.55). To support this result, it was reported by both senior students and lecturers that some topics in successive courses overlap with the content of ENS 208 (*M* = 4.15, *SD* =.96). The "overlap" refers to the similarities in the first weeks of some junior and senior level courses; this overlap causes some students to assume that they already know these topics and eventually result in their absence. For instance, the units on sensitivity analysis in linear programming and forecasting are suggested as appropriate to be moved to successive courses. To exemplify what similar contents are covered in the junior and senior year courses, lecturers stated that:

> *(Lecturer C) Most of those overlap with IE 401 such as aggregate planning, forecasting, and inventory management.*

> *(Lecturer D) I would say any subject that constitutes the first few lectures of a latter course should be omitted. We need to gradually use them in modelling or computational thinking.*

3.2 Can students establish the relationship among units at the end of semester?

Students indicated, in the questionnaires and interviews, that topics are somewhat interrelated and built upon each other leading to become familiar with the IE profession as well as the fundamental topics in the field. In this respect, current students partially agreed on being able to relate different topics to each other (*M* =3.58, *SD* = 1.15) whereas senior students reported that they managed to build relationship among different topics in ENS 208 (*M* = 3.72, *SD* = 1.09). Two current students pointed out that:

> *(Student G) I think topics are interrelated. For example, we have just started to study a new topic which is based on a previous topic covered in this course.*

> *(Student H) Yes, topics are interrelated but they sometimes remain too theoretical despite the fact that they are not too complicated.*

As another indicator demonstrating the extent of students' establishing relationships among units and overall success of the course, we consulted on the end of year achievement scores in two semesters of 2016-2017 academic year. Even though current (*M*=4.11) and senior students (*M*=3.51) thought that they are familiar with the profession as a result of this course, 36% of the students could not get a passing grade in Fall 2016 whereas it raised to 54% in Spring 2017.

[5] To interpret the results of items assessed on a 5-point Likert scale in students' questionnaires, mean score intervals are determined as follows: Disagree: 1.00 - 1.79, Partially Disagree: 1.80 – 2.59, Undecided: 2.60 – 3.39, Partially Agree: 3.40 – 4.19, Agree: 4.20 – 5.00. *M* denotes mean scores; *SD* denotes standard deviation.

4 Conclusion

In terms of the complexity of the topics and formulated outcomes referring to higher-cognitive skills, senior students and lecturers agree that the course appears to be above the cognitive level of students who do not possess any prior background about the field. Students also frequently declared that the current curriculum comprises of subjects that are too theoretical or somewhat complicated. Thus, it is suggested to include more generic concepts and fundamental notions that belong to industrial engineering field such as systems thinking, decision making and problem solving. While doing this, the curriculum should also be aligned with technological developments and needs of the society as they stand out as the major motivational challenges. While training the industrial engineers to work towards the traditional goals of profit maximization or cost minimization, other goals such as minimizing the negative impacts on society and environment shall be considered along. Nazzal et al. (2015) suggest that industrial engineers should be aware of such goals and must also be trained to apply their skills to solve problems with a united focus on profitability and sustainability. In this respect, a sustainability perspective should also be integrated into an introductory level course while including more fundamental notions.

It is crucial to align learning outcomes with the main goal of the course to enable learners to equip with intended skills. In our case, the inappropriateness of the learning outcomes with the main goal of the course as revealed by the lecturers was confirmed by a high percentage of the failure of the students. Surprisingly, the majority of the students believe that the course provides connections among various content units.

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