6-2007

A model curriculum for service systems engineering using a Delphi technique

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AC 2007-293: A MODEL CURRICULUM FOR SERVICE SYSTEMS ENGINEERING

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A Model Curriculum for Service Systems Engineering

Abstract

Over the past 100 years, the US economy has evolved from one based primarily in the goods-producing sector (agriculture, manufacturing, and mining) to the service sector. Today the service sector accounts for more than 80% of US Gross Domestic Product and more than 85% of the workforce. In fact, today many engineering graduates go on to work in service sector industries instead of more traditional manufacturing industries. In part, the service sector may be such a large segment of our economy because its processes are highly inefficient. Engineering problem-solving and talent, if properly applied to processes in the service sector, could serve to significantly increase efficiency and reduce costs, similar to advances made in the goods-producing sector over the past century. In 2003 Michigan Tech received a planning grant from the National Science Foundation to define curricular characteristics for Service Sector Engineering through a Delphi Study. Armed with these characteristics, a workshop was convened at Michigan Tech in August 2006 to define a Service Systems Engineering curriculum. Workshop participants consisted of faculty from several universities as well as industry leaders interested in engineering for the service sector. An additional grant from NSF's Course Curriculum and Laboratory Improvement (CCLI) program was recently awarded for the implementation of this curriculum.

Introduction

We are living in a service economy and our educational system has failed to keep pace to provide employers with graduates meeting the demands of the service sector. Over 80% of the economic activity in the United States is within the service sector[1] with similar high rates in other developed countries.[2] This sector is also growing; between 2000 and 2005 employment in this sector grew by 2.7 million while employment in the other sectors shrank by 2.1 million.[3]

A recent report by the National Academy of Engineering[4] described how innovation and productivity gains in service industries positively affect the whole economy, but the academic community could do more to meet the needs of service businesses. They indicate that the needs of the service industry could be better meet by adapting Industrial Engineering concepts and methodologies to services. The National Science Foundation started the Service Enterprise Engineering program in 2002 to focus on the "design, planning and control of operations and processes in commercial and institutional service enterprises."[5] Universities are beginning to respond by creating educational programs to address the design needs of service enterprises, mostly at the graduate level.[6,7] This paper describes the development at Michigan Tech of the first undergraduate degree program to address the unique engineering needs of the service economy.

The process used to design the curriculum relied heavily on service industry professionals. A group of professionals participated in a Delphi Study in order to define the characteristics of a Service Systems Engineering program. With these results, a Curriculum Planning Workshop was held to bring together service industry professionals with our team of academics to transform the program characteristics into courses and a curriculum.

Delphi Study Results

A Delphi Study is a consensus-building forecasting technique that has been used by organizations, agencies, and corporations for making predictions and setting agendas. It was developed as a management tool but it is beginning to gain acceptance as a curricular development tool.[8-11] The Delphi Study technique lends itself to reaching a consensus without the need for face-to-face meetings among panel members, making the study relatively easy to implement, especially for a panel with broad geographic representation among its members. For these reasons, a four round Delphi Study was conducted to reach consensus on the curricular requirements for a Service Systems Engineering program.

In December 2003, a brainstorming session was conducted on Michigan Tech's campus with industry leaders to help us identify topics that might be important for the curriculum. This provided the initial list of curricular topics for the Delphi Study.

Then a diverse panel of experts was recruited to participate in the study. Approximately 21 leaders from a range of service industries agreed to participate. The major service sectors represented were: 1) universities, 2) health care services, 3) insurance, 4) banking and financial services, 5) legal services, 6) technology and engineering services, 6) shipping and transport, 8) consumer and retail services, 9) utilities and communications, and 10) community services.

The results of the Delphi study produced a list of six broad curricular categories, each with several defining characteristics. These are listed in Table 1. Details of the study can be found in a previous paper.[12]

Table 1: Categories and Characteristics of Service Systems Curriculum

Category	Characteristics
Analysis Skills	Problem Solving Economic Decision Analysis Risk Analysis Cost Estimating Probability & Statistics
Interpersonal Issues	Professional Responsibility Verbal Skills Leadership Technical Writing Facilitator Skills Team Building
Business Management	Project Costing Business Planning Change Management
Service Processes	Performance Measurement Flowcharting Work Task Breakdown
Operation of Service Systems	Process Evaluation & Improvement Quality Improvement Customer Relations Risk Management
Management of Service Systems	Scheduling Budgeting MIS

Planning Workshop

On August 2 & 3, 2006 a workshop was held to distill the information gleaned from the Delphi Study into a series of courses and a structure for the curriculum. In addition to the project leaders, 14 external industry and academic experts participated in the workshop.

The first task of the workshop was to identify the program objectives and outcomes. After breaking into four groups the participants came up with a preliminary list of "objectives and outcomes" that are shown in Table 2. Some of the sentiments expressed are best characterized as program objectives and others as outcomes. It was up to the team to develop them out into a workable set of Program Objectives and Program Outcomes which can be used in program assessment.

Table 2: Service System Engineering Preliminary Program "Objectives and Outcomes"

1. Demonstrate leadership; in facilitating informed decisions regarding improving service systems
2. Ability to query managers to define problems and to know what decision is required
3. Develop "client focused" mindset
4. Understand differences and similarities of manufacturing/services
5. Ability to use specific tools and language
6. Systems viewpoint
7. Adaptive real-time decision making
8. Adapting to constant change
9. Understanding demand chain management
10. Develop effective written and verbal communication skills
11. Apply tools and techniques and evaluate results
12. Connect theory and practice; presentation of case studies and projects and ability to interact
13. Problem solving
14. Customer problems: cost, quality, process time, customer "feel", customer satisfaction via surveys
15. Design and innovation of processes (interaction of products and services)
16. Entrepreneurship
17. Collect data, analyze, innovate, implement, & design
18. Understand financial matters
19. Cost/time tradeoffs – decision making

Formalized Program Objectives and Program Outcomes

In order to facilitate our continuous improvement process, the program objectives were modified from our multidisciplinary Bachelor's of Science in Engineering program. These outcomes are shown in Table 3:

Table 3: Service System Engineering Program Objectives

1. A sound technical foundation with a Service Systems Engineering focus and the flexibility to pursue professional interests in areas outside of engineering that could lead to a wide variety of career paths.
2. In-depth technical preparation in Service Systems Engineering that could serve as a springboard to professional degree programs such as the Master of Engineering.
3. The knowledge, skills, and attitudes needed to facilitate a lifetime of professional success. These attributes would include excellent communication skills, an understanding of ethical and global issues, and a commitment to life-long learning and professional development.
4. The ability to function on multidisciplinary teams that extend the traditional boundaries of engineering.
5. The ability to design and improve systems and processes that provide services by applying a systems perspective coupled with a thorough understanding of the customer.

It was found that the program outcomes suggested by the Engineering Accreditation Commission of ABET[13] nearly covered the outcomes suggested by our industry participants. A single additional outcome was added to completely cover the list. The Program Outcomes are shown in Table 4.

Table 4: Service System Engineering Program Outcomes

(a) An ability to apply knowledge of mathematics, science, and engineering
(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
(d) An ability to function on multi-disciplinary teams
(e) An ability to identify, formulate, and solve engineering problems
(f) An understanding of professional and ethical responsibility
(g) An ability to communicate effectively
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) A recognition of the need for, and an ability to engage in life-long learning
(j) A knowledge of contemporary issues
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
(l) An ability to use engineering judgment to make decisions relating to systems, processes, and components.

To insure that the final Program Objectives and Program Outcomes define a program close to the vision expressed by our industrial participants in our workshop, a mapping was made. This mapping shows that all of the preliminary objectives and outcomes are contained in the final ones. This mapping is shown in Table 5:

Table 5: Mapping Between Preliminary Objectives and Outcomes and the Final Program Objectives and Program Outcomes

1. Demonstrate leadership **(outcome d)**; in facilitating informed decisions **(outcome l)** regarding improving service systems **(outcome c)**
2. Ability to query managers to define problems **(outcome e)** and to know what decision is required **(outcome l)**
3. Develop “client focused” mindset **(objective 5)**
4. Understand differences and similarities of manufacturing/services **(outcome a, knowledge of engineering (course content))**
5. Ability to use specific tools and language **(outcome k)**
6. Systems viewpoint **(objective 5)**
7. Adaptive real-time decision making **(outcome l)**
8. Adapting to constant change **(combined with 7)**
9. Understanding demand chain management **(outcome a, knowledge of engineering (course content))**
10. Develop effective written and verbal communication skills **(outcome g)**
11. Apply tools and techniques **(outcome k)** and evaluate results **(outcome ?)**

12. Connect theory and practice; **(outcome k)** presentation of case studies and projects **(teaching technique, not outcome or objective)** and ability to interact **(outcome d)**
13. Problem solving **(outcome e)**
14. Customer problems: cost, quality, process time, customer "feel", customer satisfaction via surveys **(objective 5 (most is course content))**
15. Design and innovation of processes (interaction of products and services) **(outcome c)**
16. Entrepreneurship **(outcome h and outcome j)**
17. Collect data, analyze, **(outcome b)** innovate, implement, & design **(outcome c)**
18. Understand financial matters **(outcome c and outcome h)**
19. Cost/time tradeoffs **(outcome c)** – decision making **(outcome l)**

The Program Objectives and Outcomes, along with the categories and characteristics of a Service Systems Engineering curriculum, served as the basis for the development of the new courses.

New Courses

At the workshop the participants defined eight new courses that will be implemented with the new program. A short description of each one is given below.

SSE2100 The World of Service Systems Engineering: This introductory course covers the evolution of service systems engineering within the broader context of engineering as well as careers and professional practice within the discipline. Advanced service system engineering topics such as optimization, simulation, and quality tools will be introduced. This course will use many examples from service industries to illustrate its points.

SSE2300 Service System Design and Dynamics: This course introduces a systems perspective in solving complex problems. How systems are designed and implemented will be a focal point and topics such as simulation, life cycle, and regulation will be introduced.

SSE3200 Analysis and Design of Web-based Services: The focus of the course will be the strategy behind developing web-based service systems. Topics will include flowcharting, cost estimating, performance measurement, and alpha and beta testing. The course will include a semester project that demonstrates the use of these tools.

SSE3400 Human Influences on Service Systems: The goal of this course is to help students develop an understanding of the social, cognitive, and cultural influences on individual and group behavior in the context of service systems. Students will be introduced to methods for assessing human perceptions, such as surveys, focus groups, and structured interviews. The design of the service interface for human interaction will also be explored.

SSE3500 Service System Operations: This course focuses on the operation of service systems in a customer-focused environment. Topics covered will include work task breakdown, performance measurement, and process evaluation and improvement. Supply chain, demand management and lean practices will also be introduced.

SSE3600 Optimization and Adaptive Decision Making: Techniques in optimization and adaptive decision making will be introduced. The fundamentals in linear, integer, and goal programming will be applied to real-world problems with a service systems focus. Adaptive decision making techniques, including Bayesian analysis, fuzzy systems, and neural networks, will also be investigated.

SSE4300 Project Planning and Management for Engineers: The various stages in a project life cycle will be defined and explored such as planning, defining metrics, execution, completion, and maintenance. Basic project management tools such as CPM, PERT, Gantt, and budgeting will be introduced. Change assimilation in the context of project management will also be a course topic.

SSE4600 Managing Risk: Risk definition and identification in terms of financial, human, legal, and physical constraints will be introduced. Techniques for analyzing and managing risk such as FMEA and reliability studies will be covered. Other topics will include risk elimination, mitigation, and tolerance.

Curriculum Content

Using these courses as the core, the whole curriculum was developed with several constraints. Enough of the "traditional" topics (statics, mechanics of materials, thermodynamics, etc.) were intentionally included in the program to: a) develop students' problem-solving skills, b) enable our graduates to pass the Fundamentals of Engineering exam to obtain eventual licensure, and c) to ensure our external constituencies (including ABET) that the graduates of the program have a quality engineering education. The resulting curriculum consists of 128 semester credits and it can be broken down as:

University defined General Education		22
Mathematics		15
MA1160 Calculus with Technology I	4	
MA2160 Calculus with Technology II	4	
MA2320 Elementary Linear Algebra	2	
MA3520 Elementary Differential Equations	2	
MA3710 Engineering Statistics	3	
Science		11
CH1100 General Chemistry	4	
PH1100 Introductory Physics Laboratory I	1	
PH2100 University Physics I - Mechanics	3	
PSY2000 Introduction to Psychology	3	

Engineering Core		26
CS1121 Computer Science 1	3	
ENG1101 Engineering Analysis & Prob. Solving	3	
ENG1102 Engineering Modeling & Design	3	
ENG2120 Statics & Strength of Materials	4	
MY2100 Intro to Materials Science & Engineering	3	
EE3010 Circuits and Instrumentation	3	
ENG3200 Thermodynamics & Fluid Mechanics	4	
ENG4900 Multidisciplinary Senior Design Project I	3	
Business/Economics		15
BA2330 Accounting 1:	3	
BA3400 Principles of Finance:	3	
BA3200 IS/IT Management:	3	
BA4760 Strategic Leadership:	3	
EC3400 Economic Decision Analysis	3	
Service Systems Engineering		29
SSE2100 World of Service Systems Engineering	3	
SSE2300 Service Systems Design	3	
SSE3200 Web Based Services	3	
SSE3400 Human Interactions in Service Systems	3	
SSE3500 Operations of Service Systems	3	
SSE3600 Optimization and Adaptive Decision Making	3	
SSE4300 Project Planning and Management	3	
SSE4600 Managing Risk	3	
MET4400 Simulation	3	
MEEM4650 Quality Engineering	3	
Electives		9

Continuing Work

The first students will enter the program in the fall semester of 2007. This will be a group of first and second year students, with next year's second year students recruited from this year's undeclared engineering students. Presently the development of the courses that will be taught next year and in the fall semester of 2008 is occurring. These courses are SSE2100, SSE 2300, SSE3400, and SSE 3500. The remaining four courses will be developed in the 2007-8 academic year. Assessment of the effectiveness of each course will be done as they are taught, as well as the effectiveness of the overall program as our students move through it. Adjustments will be made as problems come to light.

Conclusion

The Service System Engineering curriculum presented in this paper represents a significant milestone in the evolvement of the engineering discipline. It will help to meet the needs and challenges of today's and future employers. It is critical for future economic development that a program of study be available for engineering students that serves the needs of the service sector.

The process used in developing the Service System Curriculum forms a model for effectively incorporating the needs of the program's constituents into the curriculum.

Acknowledgement

The authors gratefully acknowledge the support of the National Science Foundation for the conduct of this project through grant EEC-0343187 and DUE-0618537.

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