Defining a Curriculum for Service Systems Engineering

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ABSTRACT

The U.S. economy has gradually changed from one based in agriculture, to one focused on manufacturing, to one now that relies heavily on the service sector. The service sector, including governmental agencies, retail stores, the entertainment business, public utilities, and providers of similar services, now makes up more than 80% of the total U.S. economy. Engineering programs, which typically have their roots in the era of manufacturing, have a focus on the design and fabrication of "products" rather than the design and creation of service systems. While curricula such as engineering management and industrial engineering provide some support to service systems engineering, their legacies are tied to the manufacturing sector, and as a result, they are not optimized to support the service sector. With this in mind, a Delphi Study was performed to identify the features, characteristics, and topics relevant to a service systems engineering curriculum. This paper describes the planning, conduct, and results of the service systems Delphi Study and how this information is being used to establish a new engineering degree program at Michigan Tech.[1]

Delphi Study

In September 2003, Michigan Tech received a planning grant from the Department-Level Reform program of the National Science Foundation (NSF) to define a Service Systems Engineering (SSE) curriculum with the help of industry leaders. Using our recently completed Delphi study we have identified several components of a curriculum for this new discipline that are presented here.

Panel of Experts

A key to conducting a Delphi Study for curricular design is to identify and recruit an appropriate panel of experts. For our planning grant activities, we contacted program officers at NSF, attended an NSF-sponsored conference on engineering the service sector, met with individuals from various industrial advisory boards associated with Michigan Tech,

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and networked with others identified through our efforts. We sent a letter to potential panel members asking for their assistance in defining the curriculum.

Approximately 21 leaders from a range of service industries agreed to participate as members of our panel of experts. The major service sectors represented were: 1) universities, 2) health care services, 3) banking, insurance, and legal services, 4) technology and engineering services, 5) shipping and transport, 6) consumer and retail services, 7) utilities and communications, and 8) community services. It should be noted that not all panelists returned all survey rounds, so the sample size (n-values) differed slightly from one survey round to the next. The years of experience for the panelists ranged from 6 to 43 years with a mean of 22 years. Consultant was the most frequently checked occupation category (n = 4).

Brainstorming Session

In December 2003, we conducted a brainstorming session with several industry leaders on the campus of Michigan Tech to help identify topics that might be important for the curriculum. The authors of this paper also participated in the day-long session.

Round 1 – Delphi Study

After establishing our panel of experts and identifying potential curricular topics through our brainstorming session, we began the Delphi Study. For the first round of the study, we developed a survey instrument that was based on examples from previously successful curricular Delphi studies. This instrument contained several categories and characteristics that might be relevant to a Service Systems Engineering curriculum. In the first round, experts were asked to accept, modify, delete, or add to the list of categories and characteristics on the instrument. Panel members then had several options: 1) they could state that an entire category should be deleted, 2) they could select individual characteristics from each list for deletion, 3) they could add to the list of characteristics within a category, or 4) they could rename individual characteristics. Panel members were also allowed to move characteristics from one category to another if necessary. In developing our instrument for round one, we took care to ensure that all categories and characteristics were listed randomly.

The survey for Round 1 consisted of 9 major curriculum sectors/categories, each containing multiple characteristics. A total of 50 characteristics were available across the 9 categories. We asked survey respondents to Accept or Reject each characteristic and to provide specific comments about other items that needed to be included, or general comments. We obtained a variety of demographic data: gender, years of experience, terminal degree, and occupation. The Round 1 survey was distributed by regular mail, and responses were

returned either by mail or facsimile. Nine of the 50 items were rejected by greater than 50% of the respondents and we received many valuable comments and suggestions for characteristics to add.

Round 2 – Delphi Study

Based on the Round 1 survey data we added and deleted items and reorganized the curricular topics into 6 major categories: Analysis Skills, Interpersonal Issues, Business Management and Finance, Service Processes and Systems, Management and Operation of Service Systems, and Public Policy and Law. We asked respondents to rate each item on a 5 point Likert scale with "1" denoting "Not Important" and 5 "Important." To compare mean scores of items we performed an analysis of variance, treating respondents as blocks and items as treatments. We conducted this analysis for each major category. If we found a significant difference among item mean scores ($p < 0.05$) we then compared items using Bonferronni pairwise comparisons. We also asked each respondent to rate the 6 main categories.

We received n = 20 completed surveys in Round 2. Of the 6 main categories, the "Public Policy and Law" category received the lowest overall score (mean = 3.4), with "Analysis Skills" and "Interpersonal Issues" receiving the highest mean scores of 4.5. Five of the 6 categories had significant differences among item mean scores, the exception being "Public Policy and Law" in which all items received uniformly low scores with means ranging from 3.1 to 3.7. Within the category "Analysis Skills", computer programming and database design received significantly lower mean scores. The mean scores for the other items were not significantly different. In "Interpersonal Issues", public relations and dispute resolution received low scores. In "Business Management and Finance" marketing had the lowest mean and project costing and change management the highest scores. Other characteristics receiving significantly lower scores within their categories were simulation (Service Processes and Systems) and human resources (Management and Operation of Service Systems). Items with mean scores significantly lower than the other items within a category were eliminated for subsequent Delphi rounds.

Round 3 – Delphi Study

In Round 3, each respondent was requested to rank order the items within each major category. The six categories each contained approximately 6 items of interest, and therefore, an item rank ordered as 1 was the most important, and an item rank ordered as 6 was the least important. The major topic categories were also rank ordered based on their importance. Treating each respondent as a block and the 6 items as the treatments, we employed Friedman's test to check for significant differences ($p < 0.05$) between mean rankings. If

significant differences were found we conducted pair-wise comparisons among the mean rankings to further test for differences.

We also requested each respondent to identify 10 of 36 characteristic items that they thought should be included in a service systems curriculum. We calculated the fraction of respondents who checked each item and compared the calculated proportions using an analysis of means for proportions.

We received n = 19 responses for Round 3. Considering the 6 major categories, we found that there were significant differences among the mean rankings (p = 0.019). The lowest mean rankings were associated with interpersonal skills and analytical skills (Table 1). It should be remembered that a lower value for the mean rank indicates greater importance.

Table 1. Mean Rankings for 6 major categories.

Category	Mean Rank
Interpersonal Skills	2.08
Analysis Skills	2.58
Business Management	3.25
Service Processes	3.42
Operation of Service Systems	4.25
Management of Service Systems	4.92

In considering the rank order means associated with the items within the six major categories, the statistical analysis revealed several conclusions, as shown in Table 2. Within the category "Analysis Skills", there were significant differences among the mean rankings (p = 0.021). The highest mean rank (least important item) was received by simulation (mean = 4.63) and the lowest mean (most important item) was received by probability and statistics (mean = 2.79). For the category "Interpersonal Issues" there were no significant differences among the mean rankings (p = 0.11), as means ranged from 3.1 for verbal skills to 4.6 for facilitator skills. For "Business Management", the differences in means were borderline significant (p = 0.06). The lowest mean rank was 2.8 for project costing and budgeting and the highest mean rank was 4.5 for cost accounting. In the category "Service Processes" the mean ranks were significantly different (p = 0.01). The performance measurement item had the lowest mean rank (2.3) and lean concepts the highest mean rank (4.6). For "Operation of Service Systems" the mean ranks were significantly different (p = 0.002). Process evaluation and improvement received the lowest mean rank (2.2) and safety the highest (4.8). In "Management of Service Systems" the item mean ranks were significantly different (p = 0.017) ranging from 2.6 for scheduling to 4.7 for liability.

Table 2 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

In considering the proportion response (fraction of respondents checking an item as being one of the ten most important items in the survey), three of the 36 items evaluated received significantly more selections than the other characteristic items. These items were Problem Solving (13 of 19), Economic Decision Analysis (11 of 19), and Technical Writing (11 of 19).

We then examined in detail the combined results of Rounds 2 and 3. This examination included assessing the relationship between the item mean scores from Round 2 (large value indicates greater importance) and item mean rank order from Round 3 (small value indicates greater importance). The relative importance of a characteristic item was judged by comparing its mean Round 2 score to the overall mean of Round 2 and its mean rank from Round 3 to the overall mean rank from Round 3. High priority items were considered to be those characteristic items with mean ranks below the average and above average mean scores, whereas an above average Round 3 mean rank and below average Round 2 mean score indicated a low priority characteristic item and a candidate for elimination. We also conducted a principal components analysis to produce a composite score for each characteristic to facilitate prioritization of characteristics.

Thirteen characteristics had below average Round 3 mean ranks and above average Round 2 mean scores. Figure 1 shows the results from this analysis; in this figure, items in the

lower right corner of this were deemed more important (higher than average on the Likert scale, lower than average on the ranking). The best composite scores were attained by the characteristics of process performance measurement and of process evaluation and improvement. The remaining characteristics with below average Round 3 ranks and above average Round 2 mean scores were task breakdown, change management, technical writing, professional responsibility, quality improvement, leadership, verbal skills, risk analysis, project costing, and flowcharting (see Figure 1). These characteristics received among the best composite scores from our principal components analysis as well. Other characteristics that received high composite scores that are not shown in Figure 1 were scheduling, customer relations, planning, and probability and statistics.

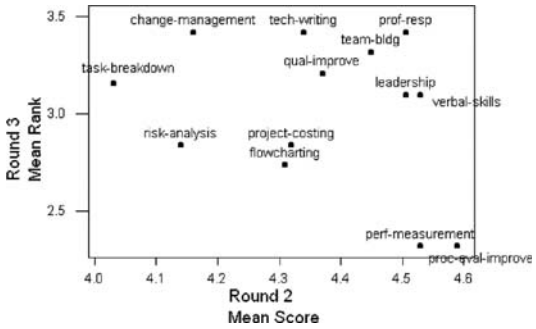

Figure 1. Results from Rounds 2 and 3

Round 4 – Delphi Study

A new survey instrument was developed based on the results from Rounds 2 & 3. For this round, surviving categories and characteristics were presented to the panelists who were asked to rate them as "Yes" (the topic must be included in the service systems curriculum) or "No" (the topic need not be included in the curriculum). Items were selected for inclusion when at least 75% of the panelists agreed that they must be a part of the service systems curriculum. Table 2 gives the results from this final round of the Delphi Study. The results from the Delphi Study are now being used to design the specific courses that will make up the service systems engineering curricula. The challenge will be in making sure that the curriculum we design is viewed as an "engineering" curriculum in the eyes of external constituencies. One of the possibilities that we are considering is to include enough "traditional" topics (statics, mechanics of materials, thermodynamics, etc.) in the program to: a) fully develop students problem-solving skills, b) satisfy external constituencies (including ABET) that this really is an engineering degree program, and c) enable our

graduates to pass the Fundamentals of Engineering exam to obtain eventual licensure. We will be working in the coming year to fully develop the courses in this innovative new program.

Curriculum Implementation

In August 2006, a 2-day workshop will be held on Michigan Tech's campus to distill the information gleaned from our Delphi Study into a series of courses and a structure for the curriculum. Participants in the workshop will consist of 8-10 industry and academic leaders who served on our panel of experts as well as project leaders. The results from this workshop were presented at the SSME workshop.

The proposed service systems engineering program will be established using the structure of Michigan Tech's ABET-accredited Bachelor of Science in Engineering program. The BSE curriculum has been used to introduce several other degree programs at MTU, e.g., environmental and biomedical engineering. The 2-day workshop focused on defining the engineering emphasis associated with service systems engineering. Based on the findings from our planning grant, we anticipate that the Workshop will identify approximately 7-9 courses for the engineering emphasis area. The workshop will also seek to pinpoint technical electives for the curriculum.

Accreditation Issues

We plan to initially launch our program through our existing BSE program, ensuring that our students graduate from an ABET-accredited program. As the program becomes more firmly established, we anticipate that it will evolve into a discipline in its own right. It should be noted that in the early 1980s, our environmental engineering program was started through the BSE and has now evolved into a separate discipline. As more universities establish SSE programs, ABET will likely respond by recognizing SSE as a discipline, similar to the evolution of environmental engineering. Based on our past experiences, as ABET begins to recognize the emerging discipline, they will appoint a committee to determine discipline-specific outcomes and a parent professional society for SSE. In forming this committee, ABET will likely rely heavily on universities who have already worked to establish programs on their respective campuses. At Michigan Tech, we are committed to being involved in this exciting curricular development and will work through our established contacts within ABET to gain national acceptance for Service Systems Engineering. One of the authors is currently the VP for Education for ASME and is ASME's representative on an ABET task force to look into Service Systems Engineering. Results from this activity will also be presented.

Summary and Conclusions

The Delphi technique for consensus-building was successfully employed in this study to define the characteristics of an emerging engineering discipline – Service Systems Engineering. Through input from a panel of experts, elements of the curriculum were identified to meet the needs of service sector industries. Through these planning activities we are now poised to begin the development of a curriculum aimed at service systems engineering.