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House of Quality Assessment of Business Skills Required by Manufacturing Engineering Graduates*

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Continuing need for quality improvements and stronger connections between educational institutions and their stakeholders (customers) are moving institutions to explore novel assessment tools and curriculum design methods. These assessment tools need to focus on specific institution goals and specific groups of stakeholders. This presents a very different problem than that addressed in the broad questions and surveys that look at larger educational issues. This paper presents an assessment tool based on the House of Quality (HOQ) approach. The tool is used to assess the business skills required by manufacturing engineering graduates for a northeastern regional university. Specific results from this study are presented as well as a general formulation of the assessment method.

INTRODUCTION

WE IN MANUFACTURING education, like other organizations, are becoming ever more aware of the need to assess the desires and requirements of our customers. This need is motivated from a variety of sources; not the least of which is ABET accreditation. ABET explicitly requires assessment with evidence of a link to program improvement. These requirements also emphasize the need to define and measure goals that are institution specific [1]:

> Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured.

This need for assessment leads to the difficult question of determining who the customers of an academic institution are. Are the customers the students, the parents, the companies that hire our students, the faculty, the community or the society at large? All have an interest in what we do in higher education. Denton [7] identifies these same major stakeholders in engineering education. So, how do we assess the needs of this large and diverse group of stakeholders? This paper presents an approach to assessing the needs and wants of various 'customer groups' or stakeholders. Specifically, we needed to identify the business skills needed by entry level (BS) engineers in manufacturing companies.

There are some large studies of engineering skills assessments available that provide some general insight.

The study 'Integrating the Product Realization Process (PRP) into the Undergraduate Curriculum' [2] presents some interesting results and assessment methods. The purpose of this study was to identify the knowledge and skills needed by BS-level mechanical engineers to participate in the product realization process. This was a large study with input from 243 mechanical engineering programs and 66 individuals in 33 large companies. By design, the results are a broad look at US academic institutions and companies.

The study consisted of a series of surveys: first, to identify the best practices in product realization, then to evaluate the expectations of employers and evaluate mechanical engineering curricula. The study then tries to correlate the results in these categories.

A similar but smaller and less structured study [15] of aerospace suppliers used a single survey of attendees at The International Aerospace Manufacturing Technology Conference. This study again demonstrates the practice of using surveys to assess the needs of a stakeholder group.

These studies presents some general results that are interesting and the study presented in this paper will be compared to the previous results. However, these studies focus on large universities,

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large employers, and national industries. This broad focus may not be appropriate for smaller regional universities where a large percentage of the graduates typically stay in the region and work for small to medium-sized companies. Furthermore, the broad focus of the previous studies does not provide the level of data needed for accreditation assessments. The methodology presented in the PRP study is useful in that it provides a model for collecting this type of data via surveys. However, the roundtable surveys conducted in the study presented in this paper allow for much more unbiased input from the participants. The roundtable form of survey is however, much more difficult to implement and consequently more expensive and would not be appropriate for large studies like the PRP study. Finally, the House of Quality, HOQ, approach provides a structure that leads logically to program improvements as required by ABET.

While these studies certainly provide some useful insight, what is needed is assessment tools that can be applied to any particular stakeholder group involved with a particular institution or program. For example, we wanted to know what business skills a graduate of our undergraduate engineering program needed. This question needs to be asked in the context of our program's heavy emphasis on manufacturing and the high percentage of our students entering manufacturing engineering jobs. Input was needed from the primary employers of our graduates, as well as the students and the faculty.

An important requirement of the assessment tool is that it defines a clear path to curriculum improvements and program modifications to address the needs of our customers. The assessment tool presented here is based on House of Quality tools and focus-group survey techniques.

HOQ, the basic design tool of the management approach known as Quality Function Deployment (QFD) was originally developed in 1972 at the Mitsubishi Kobe shipyard site. Toyota and its suppliers then further developed the system. HOQ has been used by a wide range of Japanese and US manufacturers. Dieter [8] reports that a recent survey indicates that 71% of 150 US companies surveyed have implemented QFD since 1990. The approach has also been shown to be useful in service industries [10].

QFD focuses and coordinates resources within an organization to design, produce and market a product that customers want. While this seems like a straightforward objective, it has proven difficult even in the more tangible world of product design and becomes even more difficult when one considers education as the 'product'. The features of quality defined for products [9, 11] are difficult to apply to education. Strategic quality management in education is more than avoiding problems; it means that organizations learn from customer experiences and reconcile the needs of a wide range of stakeholders.

QFD has been demonstrated to be effective in addressing the range of stakeholders found in education. Moura and Saraiva [13] applied QFD tools to design an ideal kindergarten based on children, teachers and parents as stakeholders. Mohammad *et al.* [12] used QFD approaches to design a customer-oriented engineering department. Similarly, Bier and Cornesky [4] used QFD to design a master's degree program in acupuncture and oriental medicine. These studies demonstrate the general applicability of QFD to education but do not use the method to focus in on specific questions. Furthermore, the design of feedback mechanisms still needs to be addressed to satisfy accreditation requirements.

This paper does not attempt to present a detailed description of the HOQ tools. Rather, we will look at the application of QFD to the specific problem of the need for business skills in manufacturing engineering graduates from a small, northeastern, regional, primarily undergraduate institution. There are a wide range of texts available on QFD for the reader who wishes to explore the details of the method [3, 5, 6].

METHOD

The beauty of the House of Quality approach is its simplicity. However, it does require significant effort and care in collecting and organizing the data. In the case presented here, the first step was defining the scope of the study. The overall question was: 'What business skills are required by bachelor-level graduates of a mechanical engineering program with a heavy emphasis on manufacturing in a manufacturing job market?' The stakeholders identified were the graduates, the employers of our graduates and the faculty of the Engineering and Business Schools. One could also argue that there are other stakeholders in this question. However, we narrowed the assessment to these three groups with the emphasis on employers and students. Faculty input was primarily focused on quality improvement and design issues. These limitations in scope were self-imposed.

The first step in constructing the HOQ is to identify the demand attributes, DA (often referred to as customer attributes). This study started with an extensive focus group study of the primary employers of our graduates. This was then followed by a smaller study of the student demand attributes. The student results were primarily used to determine if there was a significantly different view of what was important between the students and the employers. The remainder of the house of quality was constructed with faculty input.

The process was started by generating a list of employers that hire the largest portion of our graduates. The top 25 employers were identified through our placement office. Twenty-two of these employers were primarily manufacturing

companies. The demand attributes were collected through a series of 6 surveys conducted in a single two-hour roundtable session. The survey format and results are presented below.

A similar process was conducted with our graduating class. This survey of the students was conducted late in the spring semester so most of the students had begun interviewing and several had already secured positions.

The demand attributes from these two groups were compared and reviewed by several faculty from the school of engineering and business to identify the process/design characteristics, probability of success, estimated difficulty and established priorities.

DEMAND ATTRIBUTES RESULTS

A series of six surveys were conducted with the representatives from the primary employers of our graduates. The survey focus groups were facilitated by a faculty member from the School of Business, a faculty Member from the School of Engineering and an outside consultant all familiar with assessment techniques and QFD methods.

Survey #1: List the top 3 skills you hire from a graduate

The goal of this first survey was to identify the main skills demanded, regardless of whether or not these demand attributes are business-engineering related. The objective was to determine if business-engineering skills are one of the top attributes sought. The results are presented in the respondents' own words; without editing or paraphrasing. However, where similar responses occurred such responses are presented in groups and each grouping was created by the authors. Correspondingly, the title of each group was created by the authors, with the goal of identifying the underlying common theme. Reporting the responses in the participants' own words is essential in avoiding facilitator bias in representing the customer's desires. Listed below are the results of Survey #1.

- **Problem solving**
  - Ability to solve problems: analysis and solution of a variety of problems and/or assignments.
  - Problem-solving reasoning: ability to arrive at conclusions based upon evaluation of facts that logically address current, immediate issue and future impact of decisions.
- **Work ethic**
  - Willingness to put in time, energy or whatever is needed to complete the task timeline and with excellence.
- **Communication skills**
  - Ability to communicate clearly (written/verbal) abstract, complex issues.
- **Other**
  - Basic intelligence—not only IQ but application of IQ: both 'book smarts' as well as 'street smarts'.
  - Ability to function as a member of a team to achieve defined goals.
  - Proven technical competence.
  - Educable—can be taught process + flow.
  - Creative.

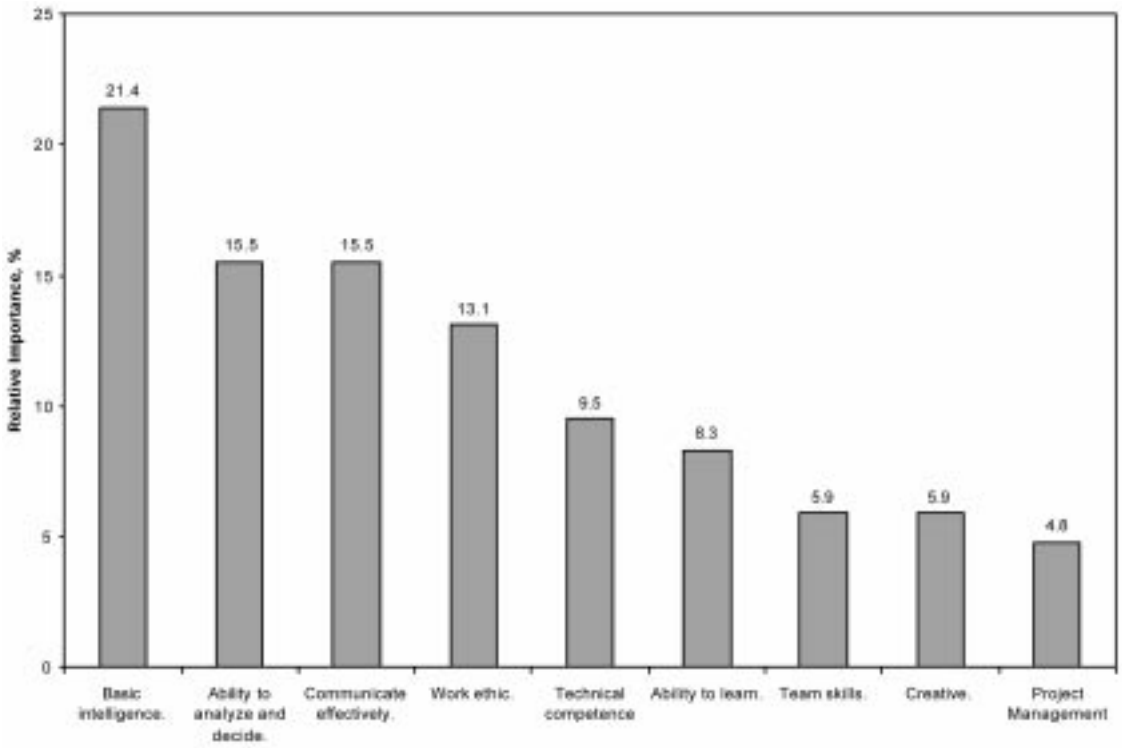


Fig. 1. Survey #2, skills hired for.

Survey #2: What is the relative importance of the skills?

The participants were shown the entire list of responses from survey #1, and asked to rank the relative importance of the top six skills. Due to the similarities of some responses, groups were identified and/or concise names were generated with the input of the participants. The ranked results are shown in Fig. 1.

This first survey asks only for the most important skills, not business-engineering-specific skills, with a goal of uncovering the extent to which business engineering skills are mentioned as important in recruitment. With the possible exception of 'technical competence,' the demand attributes identified here tend to be entirely consistent with the curriculums of both the Business and Engineering Schools. This indicates a strong potential for positive impact from the integration of these programs.

Survey #3: List the top 3 business-engineering skills you hire (expect) from a graduate

This survey was intended to focus feedback directly on the issues of main concern to this survey. The goal was to identify the primary demand attributes for business engineering graduates. The results are listed below:

- Human resources management
- Project management
- Project management skills
- Project (process) /strategic management
- Ability to maintain timelines
- Basic economics/finance
- Negotiation skills
- Change management theory
- Intelligence
- Aggressive
- Self-starting
- Understanding/focus on commercial details
- Ability to maintain timelines

Survey #4: What is the relative importance of the business-engineering skills you hire (expect) from a graduate?

This survey was intended to determine the relative importance of the primary demand attributes identified in Survey #3. The goal was to identify the top two primary demand attributes. The results are shown in Fig. 2.

The top three demand attributes are Project Management, Basic Economics/Finance, and Intelligence. It was unclear to the authors as to how intelligence fits the criteria of this scenario. This was briefly discussed with the participants as a group, and no clear rationale was generated. The participants generally agreed that intelligence was important, but also agreed that there was little that a University could do to change a person's intelligence (general mental ability). Thus, it was agreed that Basic Economics/Finance was the second most important attribute, for the purpose of this study.

Survey #5: For each of the 2 most important business-engineering skills (identified in survey #3), list the top 3 attributes.

This survey was intended to breakdown each of the two most important primary attributes into

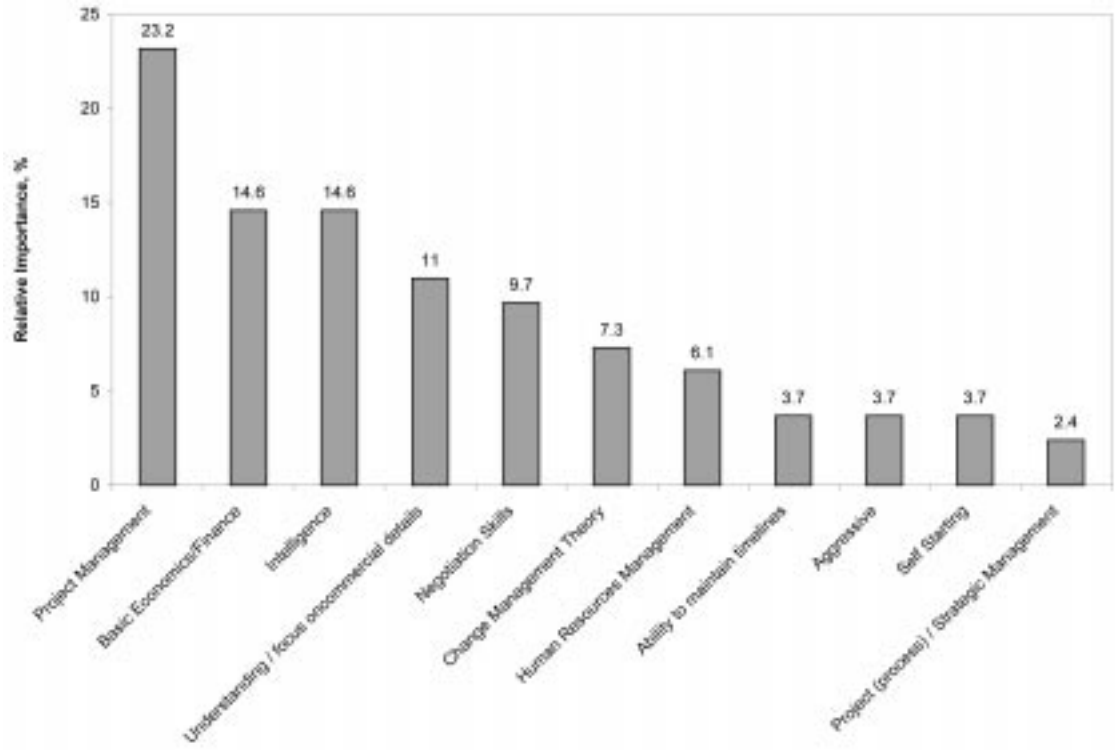


Fig. 2. Survey #4, business-engineering skills.

their more specific sub-components. That is, the goal was to identify the secondary level attributes. The results for 'project management' are presented first:

- Manage commercial details:
  - Timeline
  - Billing
  - Purchase orders
  - Subcontractors
  - Sampling, prototyping
- Team facilitation
- Leader
- Lead project team:
  - Put together & lead
  - Successful team
  - Get results from others
- Communicate (customer, management, manufacturing, accounting, etc).
- Communication
- Perception and vision
- High goal satisfaction
- Time management
- Time management/planning
- Planning
- Ability to analyze based on presented facts and reach 'workable' conclusions

Basic economics/finance considerations:

- Strategy to commercialize a product or component including marketing
- Understanding of commercial term and conditions
- P & L analysis and ability to design to a profit margin target.
- Financial statement readership analysis.
- Budget administration.
- Plan and publish/communicate:
  - Budget
  - Financial goals
  - How to finance/get capital
  - Track results
- Ability to analyze data to determine financial/market trends.
- Negotiation.
- Understanding of economic theory and application.
- Accounting/financial process understanding.
- Communication.
- Marketing instincts.

Survey #6a: What is the relative importance of the most important project management skills (identified in survey #5)?

This survey was intended to determine the relative importance of the primary project management skills identified in Survey #5. The goal was to identify the top two primary project management skills. The results are shown in Fig. 3.

The most important project management skill was 'leadership'. The second most important skills were 'communication', and 'nalysis skills'.

Survey #6b: What is the relative importance of the most important basic economics/finance skills (identified in survey #5)?

This survey was intended to determine the relative importance of the primary basic economics/finance skills identified in Survey #5. The goal was to

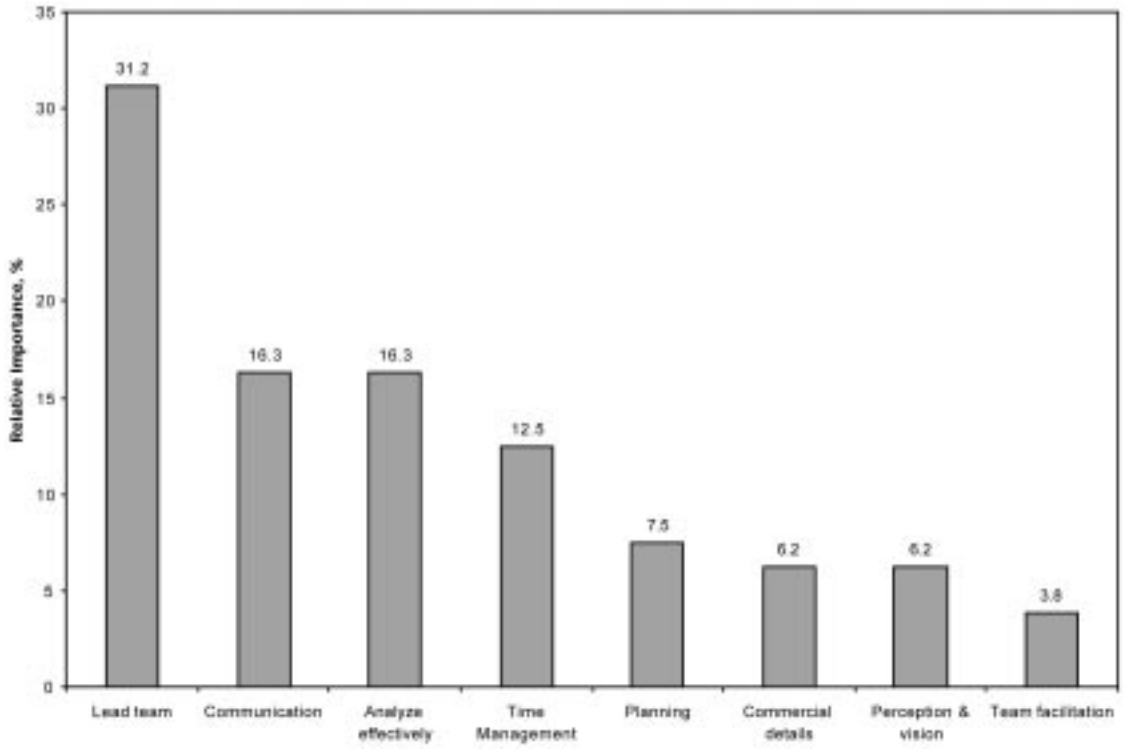


Fig. 3. Survey #6a, project management skills.

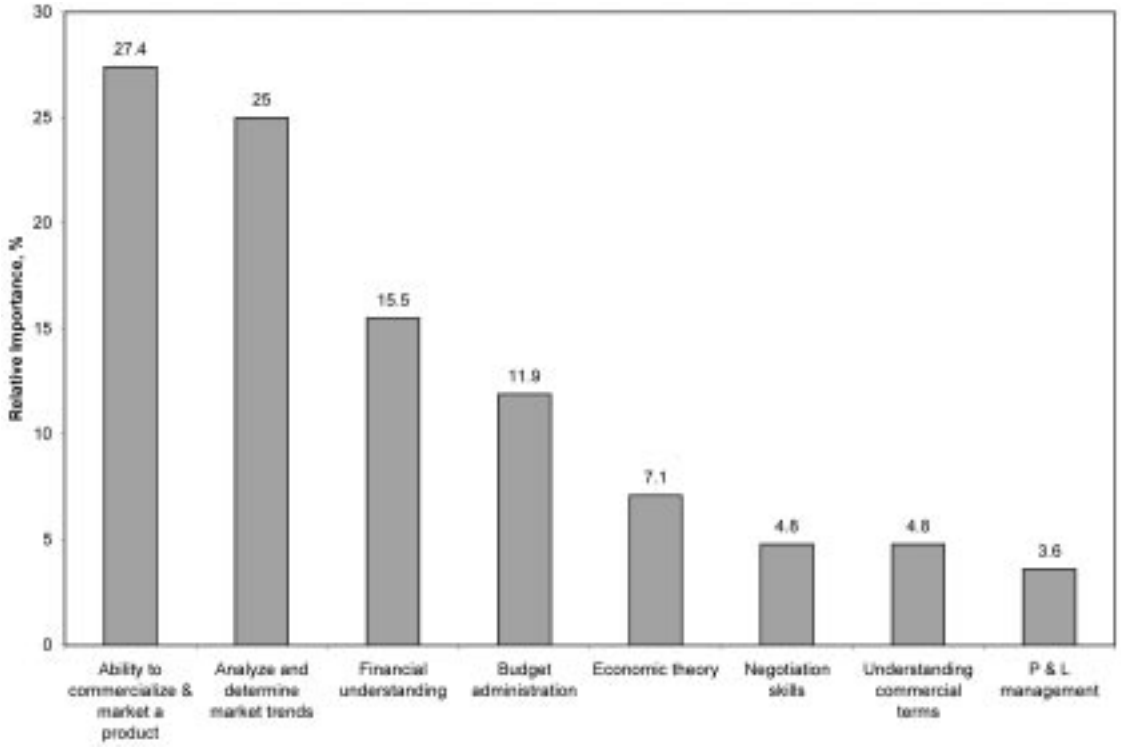


Fig. 4. Survey #6b, economic and finance skills.

identify the top two primary basic economics/finance skills. The results are shown in Fig. 4.

The most important basic economics/finance skill was 'commercialize product.' The second most important skill was analyzing market trends.

Student roundtable

A student roundtable meeting was held to seek insight from students. At this meeting, engineering seniors were asked their opinion regarding business/engineering skills and abilities our graduates should possess, and the relative importance of these abilities. The goal of this meeting was to determine if a significant discrepancy existed between the perceptions of the students and the perceptions of the managers who will be hiring them. Ultimately, this knowledge would help to refine the goals of the curricular model.

The structure of the student roundtable meeting was less formal than that of the business roundtable, as the outcome of this process was intended only to provide a basis for determining if a major discrepancy existed between the students and the business leaders. The results of the student roundtable are summarized below:

The students identified the following business-engineering skills which are presented in order of importance.

1. Task management/project management:
   a) How to divide the work.
   b) Who is impacted by us . . . ?
   c) How to prioritize jobs.
   d) How to create Gant charts/timelines.
   e) How to use the chart. . .
   f) How to estimate timelines.
2. Marketing specification (feasibility):
   a) How to do this.
   b) How to properly design a survey.
   c) How to properly conduct a survey.
3. Finance and budgeting:
   a) How to prepare bids.
   b) How to prepare proposals.

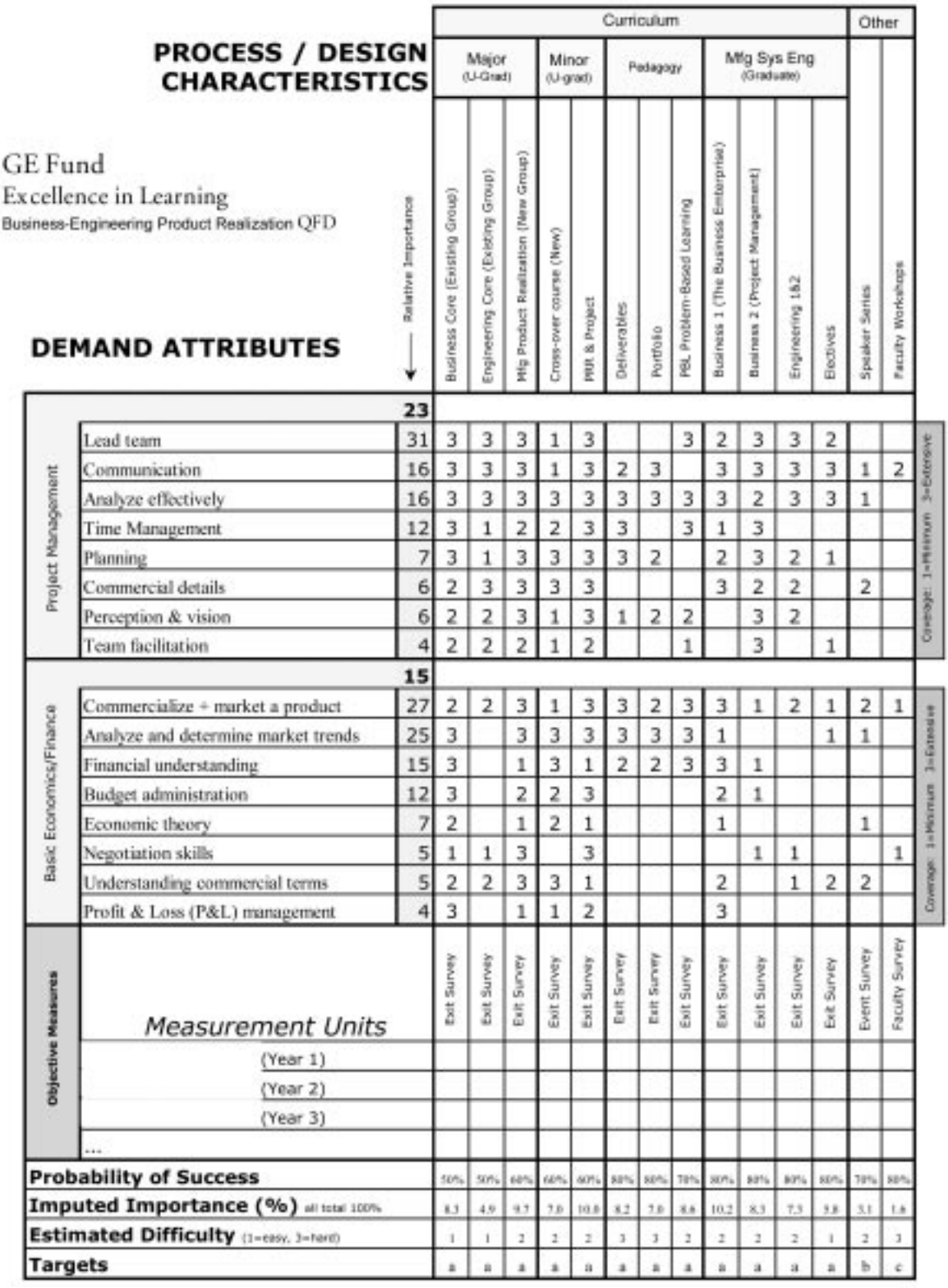
It is interesting that both the content and ranking of skills is, essentially, exactly the same for students and managers. Thus, curriculum changes that target the skills identified by the business roundtable are likely to be entirely consistent with the skills sought by the students. Accordingly, based on this we would expect little, if any, resistance by students toward curriculum changes that help achieve these skills.

HOUSE OF QUALITY

Now that a clear picture of the demand attributes have been generated, we can begin to look at ways to better serve the needs of our customers. This will be accomplished by completing the House of Quality. The final design is shown in Fig. 5.

Process design characteristics

The academic model proposed consists of two major components: curricular and non-curricular. These process-design characteristics were developed by a small committee of faculty



		Relative Importance	Business Core (Existing Group)	Engineering Core (Existing Group)	Mfg Product Realization (New Group)	Cross-over course (New)	MQL & Project	Deliverables	Portfolio	PBL Problem-Based Learning	Business 1 (The Business Enterprise)	Business 2 (Project Management)	Engineering 1&2	Electives	Speaker Series	Faculty Workshops
Project Management		23														
	Lead team	31	3	3	3	1	3			3	2	3	3	2		
	Communication	16	3	3	3	1	3	2	3		3	3	3	3	1	2
	Analyze effectively	16	3	3	3	3	3	3	3	3	3	2	3	3	1	
	Time Management	12	3	1	2	2	3	3		3	1	3				
	Planning	7	3	1	3	3	3	3	2		2	3	2	1		
	Commercial details	6	2	3	3	3	3				3	2	2		2	
	Perception & vision	6	2	2	3	1	3	1	2	2		3	2			
	Team facilitation	4	2	2	2	1	2			1		3		1		
Basic Economics/Finance		15														
	Commercialize + market a product	27	2	2	3	1	3	3	2	3	3	1	2	1	2	1
	Analyze and determine market trends	25	3		3	3	3	3	3	3	1			1	1	
	Financial understanding	15	3		1	3	1	2	2	3	3	1				
	Budget administration	12	3		2	2	3				2	1				
	Economic theory	7	2		1	2	1				1				1	
	Negotiation skills	5	1	1	3		3					1	1			1
	Understanding commercial terms	5	2	2	3	3	1				2		1	2	2	
	Profit & Loss (P&L) management	4	3		1	1	2				3					
Objective Measures	Measurement Units		Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Exit Survey	Event Survey	Faculty Survey
	(Year 1)															
	(Year 2)															
	(Year 3)															
	...															
Probability of Success			50%	50%	60%	60%	60%	80%	80%	70%	80%	80%	80%	80%	70%	80%
Imputed Importance (%) all total 100%			8.3	4.9	9.7	7.0	10.8	8.2	7.0	8.6	10.2	8.3	7.5	9.8	5.1	1.6
Estimated Difficulty (1=easy, 3=hard)			1	1	2	2	2	3	3	2	2	2	2	1	2	3
Targets			a	a	a	a	a	a	a	a	a	a	a	a	b	c

Fig. 5. House of quality.

with representation from both the business school and the school of engineering. While the details of the initiatives are institution specific, the general descriptions are listed below as a demonstration of how program changes would be incorporated into the House of Quality.

- *Curriculum:* within the curriculum, there are four main initiatives to consider:
  - A new undergraduate major: PRP product realization processes.
  - A new undergraduate minor: PRP product realization processes.

  - Pedagogy that targets 'hands-on' student processes.
  - Continuation of the graduate degree program: Manufacturing Systems Engineering.
- *Non-curriculum (other):* two main non-curriculum initiatives are recommended:
  - A speaker series, focusing on product realization processes
  - Faculty workshops, focusing on product realization processes and/or corresponding pedagogy.

While the graduate program is somewhat outside the scope of this study, it was included in the HOQ because the data collected so directly affected this program. The HOQ framework (above) displays a basic framework within these initiatives. The faculty committee filled in the relationship matrix in Fig. 5 indicating how each process characteristic affects each customer attribute. A three-point scale was used with a '3' being the strongest positive relationship.

Objective measures

Objective measurement of demand attribute skills is essential to the implementation and long-term success of the program and a requirement of accreditation agencies. The exit survey is the most effective and pragmatic means of assessing the effectiveness of most of the process characteristics in the model. Implementation will require additions or modification to current exit surveys to address the points identified in this study. Employer surveys are also used to support and verify the exit survey data.

Additional event surveys will be used for specific events like the speaker series. Also, faculty surveys will be implemented to assess the impact on faculty workshops etc. Additional assessment tools can also be added to verify survey data.

Probability of success

The probability of successfully achieving curricular content, as designed in the HOQ framework, was subjectively assessed by the faculty group. Changing core courses was determined to be the least likely to succeed due to the cultural changes this would require in the faculty and institution. While the cultural changes are being addressed in a variety of ways, including a speaker series and faculty workshops, this was viewed as one of the primary obstacles to success.

Imputed importance

The relative importance was calculated by multiplying the probability of success by the sum of the products of relationship scores weighted by the relative importance. The relative importance was then scaled to total 100. For example, the MSE course 'The Business Enterprise' was rated as most important due to its broad impact on multiple important categories and due to its (relatively) high probability of success given that the course has already been developed and successfully offered once.

Estimated difficulty

The faculty committee subjectively assessed the difficulty of executing an initiative. The evaluation considered:

- effort required to implement;
- cultural change issues with the faculty and the students;
- administrative barriers to change;
- multidisciplinary difficulties and resources required.

The ratings were again on a three-point scale with '1' being the easiest to implement.

Targets

The targets are to actually achieve the 'level' of skill indicated in the body of the HOQ. The targets specify the objective measure to be used and the target result:

- Measure 'a' = The exit survey should ask, and subsequently verify with employers, that the level of skill achieved matches the level indicated in the HOQ Academic Model. For example, undergraduate majors in PRP should rate Project Management-Team Leadership as 'strong' or 'extensive' skill achievement, resulting from classes taken in the Business Core, etc.
- Measure 'b' = The event survey should verify that the extent of knowledge achieved, by attending the lecture series, matches the level indicated in the HOQ Academic Model.
- Measure 'c' = The faculty survey should verify that the extent of knowledge achieved, by attending the workshops, matches the level indicated in the HOQ Academic Model.

SUMMARY AND CONCLUSIONS

This study presents an assessment of business skills required by manufacturing engineering graduates based on the QFD, House of Quality design tool. The method is very flexible, allowing the assessment of specific questions, from specific groups of stakeholders. Furthermore, the method allows for the integration of input from the wide variety of stakeholders typical of an educational institution. The method also presents a logical sequence for program improvements to specifically address the assessment results and develop objective measures to evaluate the effects of the changes.

Specific results for the assessment of business skills required for manufacturing engineering graduates indicate that for this institution, and its primary employers, business skills do play a role in hiring decisions, but that they are secondary to technical skills, general intelligence and

problem-solving skills. The specific 'non-technical' skills were communication, work ethics, team skills, and project management skills.

As the survey then focused on specific business skills, project management, basic economics and finance skills were identified as the top categories of skills required. While our study then focused in on these two categories, the rest of the list is interesting and important to overall curriculum design.

The areas of project management, and economic and finance skills were then further broken down and prioritized. The attributes associated with each of these skills provide detailed insight into specifically what our customers are looking for. The attributes also provide clues about possible revisions to better meet our customers' needs. The differences between these two skill categories are important.

The project management skills were very consistent with what we expected from past experience and other studies. The respondents emphasized the process oriented skills of leading teams, communication and time management. This was also consistent with the PRP study [2] and [15]. These process skills are also reflected in the 'Skills Hired for Survey' (Survey 1 and 2). Of the top skills hired for, 6 of the 9 are found in the top 25 of the PRP study. The three that were not found in the PRP study (basic intelligence, ability to analyze and decide and the ability to learn) were a result of the different survey techniques.

The survey in [15] also identified the more specific manufacturing skills of design for manufacture and lean manufacturing. Again, these are primarily attributed to differences in the survey techniques, specifically the group of respondents.

The second set of business skills required by manufacturing engineering graduates was clearly focused on technical business skills, specifically, analysis, marketing data analysis, finance and budgeting. This was not expected and clearly indicates a need to evaluate these skills. Current exit surveys and feedback mechanisms for this program did not address these types of skills. The importance of these skills is also not reflected in the PRP study.

The assessment was also made with a group of graduating students. The student assessment was less formal and less detailed because of the different assessment objective. The student results were very consistent with those of the primary employers'. It should be noted that the students were already interviewing and had been exposed to many of the primary employers and to what the employers were looking for. It would be useful to conduct the same assessment with the same students one to three years after they start their jobs. It would also be interesting to assess student expectations prior to interviewing.

Armed with these results, the faculty can now address the needs of the customers in the context of the goals and constraints of the institution. The methods described to address the assessment results include modifications to the core courses and curriculum, new courses, introduction of the formal inclusion of the product realization process into the curriculum, pedagogical changes, as well as changes to address the institutions culture. The House of Quality approach nicely leads to solutions that are institution specific and creates a clear connection between assessment and program goals. This connection is an important feature of ABET accreditation requirements.

Finally, the approach provides a measure to objectively evaluate the changes providing a long-term feedback mechanism. Specifically, the objective measures identified above provide a direct means of assessment of the effectiveness of the curricular changes.

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