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An ABET Assessment Model Using Six Sigma Methodology

Approved by:

Dr. Richard R. Shell, Dr. Ali A. Houshmand, Dr. Ronald L. Huston, Dr. Roy Eckart,
AN ABET ASSESSMENT MODEL
USING SIX SIGMA METHODOLOGY

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by
Mira Lalovic
B.S., Belgrade University, Yugoslavia, 1995
M.S., University of Cincinnati, US 1999

Committee Chair: Dr. Richard L. Shell
Abstract

Technical fields are changing so rapidly that even the core of an engineering education must be constantly reevaluated. Graduates of today give more dedication and, almost certainly, more importance to continued learning than to mastery of specific technical concepts. Continued learning shapes a high-quality education, which is what an engineering college must offer its students. The question is how to guarantee the quality of education. In addition, the Accreditation Board of Engineering and Technology is asking that universities commit to continuous and comprehensive education, assuming quality of the educational process.

The research is focused on developing a generic assessment model for a college of engineering as an annual cycle that consists of a systematic assessment of every course in the program, followed by an assessment of the program and of the college as a whole using Six Sigma methodology. This unique approach to assessment in education will provide a college of engineering with valuable information regarding many important curriculum decisions in every accreditation cycle. The Industrial and Manufacturing Engineering (IME) Program in the College of Engineering at the University of Cincinnati will be used as a case example for a preliminary test of the generic model.
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I am also indebted to the other members of my committee, including Dr. Ronald L. Huston for his support and optimism, which helped me maintain the needed confidence in achieving this goal and Dr. Ali A. Houshmand, who helped me tremendously through the years with his supreme knowledge in the area of quality and application of statistical methods which ultimately made this research work possible.

I would like to express my deepest thanks to my parents who gave me unlimited love and affection, encouraged me to work hard, supported me unselfishly, and protected me during the hard times. I dedicate my dissertation to them as a token of my love for them.
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Chapter 1. Introduction

1.1. Problem Definition

In this research, the Six Sigma methodology will be used to develop a general Accreditation Board of Engineering and Technology (ABET) assessment model supported by a robust database platform. As users require more and more functionality over the Internet for e-business purposes, a college will have intense demand for computerized data processing and results that are immediately accessible online. This unique approach to assessment in education will provide a college of engineering with valuable information regarding many important curriculum decisions in every accreditation cycle. The objective of this research is to develop a generic assessment model for a college of engineering as an annual cycle that consists of a systematic assessment of every course in the program, followed by an assessment of the program and of the college as a whole using Six Sigma methodology. The Industrial and Manufacturing Engineering (IME) Program in the College of Engineering at the University of Cincinnati will be used as a case example for a preliminary test of the generic model.

Technical fields are changing so rapidly that even the core of an engineering education must be constantly reevaluated. Graduates of today give more dedication and, almost certainly, more importance to continued learning than to mastery of specific technical concepts. Continued learning shapes a high-quality education, which is what an
engineering college must offer its students. The question is how to guarantee the quality of education.

One way of proving that an institution is adding value to education in the area of engineering and technology is accreditation by Engineering Criteria 2000 (EC 2000), issued by the ABET. EC 2000 is designed to evaluate the performance outcomes, and objectives of engineering colleges. With simple yet radical change in focus from input to outcome, the revolutionary EC 2000 provides graduates with the best chance of reaching their goals. As of September 2001, the document became mandatory. EC 2000 emphasizes alternative abilities, leaned in college, an engineer should possess upon entry into professional practice. In addition to providing students with a quality education, it is imperative for an engineering college to be accredited in order to survive and thrive in the increasingly competitive marketplace that is academia.

The criteria are even sparking worldwide educational reform. Many international institutions want their programs evaluated by EC 2000 so that their graduates can more realistically aspire to jobs anywhere in the world. For industry, a well-“produced” engineering expert is an essential. This fact further stresses the relevance of quality in engineering education. A recent engineering graduate needs to be able to work in teams and communicate with co-workers and managers both orally and in writing. Being so tightly interconnected, business and science must now speak the same language, and addressing some educational goals in business language shouldn’t come as a surprise. According to significant industry critics, an engineering graduate should be
able to evaluate the cost of developing and manufacturing a product and to assess the impact of prospective technologies on society and the environment.

Engineering colleges worldwide today stumble over these complex challenges looking for the best solutions to survive and thrive in the growing competitive marketplace, which in this case is academia [4]. One of the most powerful business strategies for improving quality in an organization is Six Sigma, a breakthrough methodology commonly used in manufacturing [58]. Companies like General Electric, Motorola, Johnson & Johnson, and Kodak are the most famous successful examples of the Six Sigma way: communication, training, leadership, teamwork, measurement, continuous improvement, and a focus on the customer. Six Sigma principles apply to any type of business, manufacturing or service industry. However, in the case of academia as a service industry the problem is very complex. Academia has several types of “customers”: students, parents, employers, graduate schools, community and society, industrial advisory councils, and professional societies. Additionally, EC 2000 and ABET accreditation requires continuous improvement in engineering education that satisfies several important factors presented in the form of learning outcomes. To ensure stated learning outcomes and quality in education by applying the Six Sigma concept, it is necessary to utilize a very complex process. However, it is not easy to apply Six Sigma method in such a demanding environment.

Six Sigma is a flexible system for improved business leadership and performance. It builds on many of the most important management ideas and best practices of the past
century, creating a new formula for successful business in the 21st century. Six Sigma is a methodology that links various established management and statistical tools in a structured manner for demonstrable quality improvement. The methodology requires the organization’s overall support: Support for Six Sigma means making sure that top management drives the effort, that sufficient resources are allocated to make it succeed, that the culture is supportive of change, and that employees develop the skills and behaviors necessary to reinforce Six Sigma efforts at the level of individual jobs and work processes. Most of all, Six Sigma requires that a business be built around an intimate understanding of the customer’s requirements.
1.2. Importance of This Research

The Accreditation Board of Engineering and Technology is asking that universities commit to continuous and comprehensive education, assuming quality of the educational process. However, quality and levels of quality are changing rapidly, and customers’ demands are expanding. TQM methodology is no longer sufficient to keep up with the changes. Yet, only 10% of universities in the United States have reached the TQM level, and many are seeking ABET accreditation [63, 49]. In recent years ABET has accredited engineering programs at 330 universities. Each of those 330 engineering colleges offers an average of five programs [4]. These numbers emphasize the problem of quality in academia. Many (most) universities do not have a structured approach to improve processes that affect key metrics [102]. A college might have a set of balanced metrics for assessment. Typically a college would find quantitative variability by plotting the changes in the metrics over time. As a result, many of the metrics do not improve.

This is the first time that a structured approach will be used to develop a generic model for assessment. Six Sigma, a breakthrough methodology for improvement, will be applied for the first time to ABET accreditation and development of a college’s competitive advantage in academia. This model will provide a detailed roadmap to continuous high-quality performance of an engineering program seeking ABET EC 2000 accreditation and more.
The newest techniques in the area of database systems will be applied to support data collection and analysis. The database system will enable a college and its programs to gather information and to implement changes accurately and in a timely fashion.

The assessment tools used in this model, including surveys and portfolios, are widely known to the world of education, but are rarely utilized in a structured and systematic way. Moreover, portfolios have not been used before as an assessment tool for an engineering program. This model introduces the technique that will make this powerful tool, which features student’s best work, a mechanism for assessing program learning outcomes as required by ABET EC 2000.

The model approaches a college as a business organization that must compete for its customers. Many college administrators have not been sensitive to outside customers such as parents, employers, graduate schools, and society, and the impact they may have on the quality of education. All of these matters will be strongly supported by the model.

The fundamental purpose of EC 2000 is an ongoing process of improvement in education across all functions. This improvement is necessary for any college’s success. The generic model is designed to thoroughly support the continuous process of improvement of an educational institution.
Chapter 2. Literature Review

2.1. Six Sigma Literature Review

The History

According to Tom McCarty, director of Six Sigma business improvements at Motorola University in Schaumburg, Illinois, Six Sigma differs substantially from quality initiatives that were prominent in the 1970s and 1980s, such as Continuous Improvement and Total Quality Management [120].

But the pursuit of quality started a lot earlier. The story begins with one of the masterminds behind the Japanese approach to quality, Joseph M. Juran. He believed that if Japan, as a nation, had not suffered through a significant emotional event when it lost World War II, the country might not have been as receptive to change. Japan’s focused efforts to recover made it willing to listen to Juran and what he had to say about quality. Prior to World War II, “made in Japan” meant poor quality. Fifty years later, “made in Japan” means world-class quality. In fact, Joseph Juran’s words and those of Dr. W. Edwards Deming, the prime catalyst behind the transformation of Japan’s industries, weren’t any different from what Deming had been telling American audiences for years. The difference was how the Japanese audiences heard and interpreted them. The Japanese have embraced his concepts and have named their highest quality award after him.
Forrest W. Breyfogle, author of *Implementing Six Sigma* [24], agrees with Deming’s philosophy and believes that many companies need to make the changes proposed by Deming in order to become more competitive. Deming’s contribution to the quality movement would be difficult to overstate. Many consider him the father of the movement. The things for which he is most widely known are the Deming Cycle, his Fourteen Points, and the Seven Deadly Diseases [58, 5, 24]. Figure 2.1 shows the three TQM pioneers.

![Figure 2.1. Total Quality Pioneers](image)

**Total Quality Management Versus Six Sigma**

In the 1970s the world of business was introduced to Total Quality Management and Continuous Process Improvement. As there are many different definitions of quality, so there are different definitions of total quality. For instance, the U.S. Department of Defense defines TQM as follows: “TQM consists of continuous improvement activities involving everyone in the organization — managers and workers — in a totally
integrated effort toward improving performance at every level. This improved performance is directed toward satisfying such cross-functional goals as quality, cost, schedule, mission need, and suitability” [49].

The rationale for total quality can be found in the need to compete in the global marketplace. To survive and thrive in a globally competitive marketplace, according to TQM, organizations must adopt a broad strategy that gives them a sustainable competitive advantage. All such strategies fall into one or more of the following categories: cost/leadership strategies, differentiation strategies, and market niche strategies. Other studies conducted on TQM (Schaffer Thompson in 1992, Opara in 1996, Hendriks and Singhal in 1997, Wimsatt in 1998) have indicated that TQM implementation improves companies' financial performance. TQM practice can lead to improved customer satisfaction, one of the most important constructs contributing significantly to financial performance [49, 6, 110]. However, the practice in many companies was to focus more on stabilizing rather than improving processes. The idea of quality “philosophers” made the whole concept seem mysterious to many people [99]. Moreover, the “regular people trying to apply quality (the non-experts) were alienated from the effort” [100]. Although Total Quality Management is less visible in many businesses today than it was in the early 1990s, it is not exactly dead. Many companies are still engaged in improvement efforts based on the principles and tools of TQM.

Six Sigma is in many ways a powerful renaissance of quality ideas and methods [24], but it is revealing a potential for success that goes beyond the levels of improvement.
achieved through the many TQM efforts. For example, Six Sigma organizations are putting process management, improvement, and measurement into action as part of the daily responsibilities of their operating managers. TQM organizations, on the other hand, left their middle managers out of the decision process, and problem-solving authority was transferred to teams over which they had no control [99]. Table 2.1 provides a review of other major TQM omissions, as well as hints on how the Six Sigma system can keep them from derailing an organization’s efforts [99, 23].

Table 2.1. Six Sigma Versus TQM

<table>
<thead>
<tr>
<th>TQM Limitation</th>
<th>Six Sigma Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of integration</td>
<td>Links to the business and personal “bottom line”</td>
</tr>
<tr>
<td>Leadership apathy</td>
<td>Leadership at the vanguard</td>
</tr>
<tr>
<td>Fuzzy concept</td>
<td>A consistently repeated, simple message</td>
</tr>
<tr>
<td>An unclear goal</td>
<td>A no-nonsense, ambitious goal</td>
</tr>
<tr>
<td>Purist attitudes and technical fanaticism</td>
<td>Tools and degree of rigor adapted to the circumstances</td>
</tr>
<tr>
<td>Failure to break down internal barriers</td>
<td>Priority on cross-functional process management</td>
</tr>
<tr>
<td>Incremental vs. exponential change</td>
<td>Incremental exponential change</td>
</tr>
<tr>
<td>Ineffective training</td>
<td>Black Belts, Green Belts, Master Black Belts</td>
</tr>
<tr>
<td>Focus on product quality</td>
<td>Attention to all business processes</td>
</tr>
</tbody>
</table>

The Six Sigma Ways

Six Sigma is a business system for achieving and sustaining success through customer focus, process management and improvement, and the wise use of facts and data [99]. There are many Six Sigma ways [23, 58, 99, 100]. Each organization should adopt the tools and approaches that get results in the most comfortable way.
Six Sigma was used first by Motorola in the early 1990s. More recent Six Sigma success stories, primarily from General Electric, Sony, AlliedSignal\(^1\), and Johnson & Johnson, have captured the attention of Wall Street. These stories have exposed the use of statistical tools within a structured methodology to gain the knowledge needed to produce better, faster, and less expensive products and services than the competition [24].

In *Basic Statistics Look for Continuous Improvement*, M. J. Kiemele wrote: “The repeated, disciplined application of the master strategy on project after project, where the project is selected based on the key business issues, is what drives dollars to the bottom line, resulting in increased profit margins and impressive return on investment from the Six Sigma training” [66]. These who implement the Six Sigma project called Green Belts, Black Belts, and Master Black Belts, are trained in the Six Sigma philosophy and methodology, which are designed to achieve aggressive, far-reaching goals by focusing on out-of-the-box thinking. “Ultimately, Six Sigma if deployed properly will infuse intellectual capital into a company and produce unprecedented knowledge gains that translate directly into bottom-line results [24].”

\(^1\) AlliedSignal has merged with Honeywell, and the name of the company is Honeywell.
The Statistical Definition of Six Sigma

The objective in driving for Six Sigma performance is to reduce or narrow variation to such a degree that standard deviation can be squeezed within the limits defined by the customer’s specification [24]. For many products, services, and processes that means a potential for enormous improvement. The statistics associated with Six Sigma are relatively simple. To define Six Sigma statistically, two concepts are required: specification limits and the normal distribution.

Specification limits are the tolerance or performance ranges that customers demand of the products or services they are purchasing. Because variability is so ubiquitous in the real world, the specification limits should be set in a way that permits some degree of imprecision in the work done. Figure 2.2 illustrates specification limits as the two major vertical lines in the figure. The target value, shown in the figure as $X$, is naturally at the exact center between the upper and lower specification limits. These specification limits are independent of the bell-shaped curve of the normal distribution, also shown in the figure. The customer expects the result to fall somewhere between the upper and lower specification limits, if not exactly in the center ($X$). It is up to the customer to decide whether or not the extreme values at the specification limits are acceptable quality levels. The values outside the customer specification limits are considered defects, failures, or nonconformities.
The bell-shaped curve in Figure 2.2 is called the normal distribution, also known as a Gaussian curve. It has a number of properties that make it an extremely useful and valuable tool in both the statistical and quality worlds. The normal curve is independent of specification limits described above. The shape of the normal curve depends solely on the process, equipment, personnel, etc., that can affect the product. It represents a summary of the empirical quantification of the variability that exists within the product manufacturing process [24]. Breyfogle described the variability as follows: The tabular information in Figure 2.2 indicates the percentage of the area under the normal curve that can be found within ±1σ units throughout ±6σ units centered about the mean, where
\( \sigma \) represents true population standard deviation. For instance, \( \pm 3\sigma \) units of standard deviation represent 99.73% of the total area under the normal distribution curve (100%). The difference of 0.27% (i.e., 100% − 99.73%) is the probability of a plant production whose product is outside of \( \pm 3\sigma \) units of standard deviation. If a process is centered, for every 100 product units, 99.73% of them, approximately 98 products, will have desired characteristics that fall within \( \pm 3\sigma \). Figure 2.2 indicates that this corresponds to 2,700 defective parts per million (ppm) of the products at \( \pm 3\sigma \). At \( \pm 6\sigma \) there are 0.002 defective parts per million.

In the situation described above, the process is centered. To address the “typical” shift of a process mean from a specification-centered value, Motorola added a shift value of \( \pm 1.5\sigma \) to the mean. This shift of the mean is used when computing a process “sigma level” or “sigma quality level,” as shown in Figure 2.3. This figure shows, for example, that a 3.4-ppm rate corresponds to a \( \pm 6\sigma \) quality level.

Figure 2.4 illustrates the impact of the \( 1.5\sigma \) shift. It illustrates that an improvement from a \( 3\sigma \) to a \( 4\sigma \) quality level is not the same as an improvement from a \( 5\sigma \) to a \( 6\sigma \) quality level. The first shift corresponds to a tenfold improvement in the defect rate, the second to a 70-fold improvement, where these comparisons are based on a \( \pm 1.5\sigma \) shifted process. A unit change in sigma quality level does not correspond to a unit change in process improvement as measured by defect rates. In other words, a shift from \( 5\sigma \) to \( 6\sigma \) is a much more difficult improvement effort than a shift from \( 35\sigma \) to \( 4\sigma \) [24].
The sigma quality level metric is controversial, because each organization has unique demands. An organization needs to understand the concept behind this metric even if it does not use the metric as a driving force within the organization [23]. This is very important to the implementation of Six Sigma tools: When it comes to implementation of Six Sigma in a service industry, the concept is the key.

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2 Figure is extended from Breyfogle’s book *Six Sigma Smarter Solution Using Statistical Methods*. 

---

<table>
<thead>
<tr>
<th>Spec. Limit</th>
<th>Percent</th>
<th>Defective ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>±1σ</td>
<td>30.23</td>
<td>697,700.0</td>
</tr>
<tr>
<td>±2σ</td>
<td>69.13</td>
<td>308,700.0</td>
</tr>
<tr>
<td>±3σ</td>
<td>93.32</td>
<td>66,810.0</td>
</tr>
<tr>
<td>±3σ</td>
<td>99.3790</td>
<td>6,210.0</td>
</tr>
<tr>
<td>±5σ</td>
<td>99.97670</td>
<td>233.0</td>
</tr>
<tr>
<td>±6σ</td>
<td>99.9999660</td>
<td>3.4</td>
</tr>
</tbody>
</table>
How the Organizations of Today Are Improving Process Quality

In 1982, Motorola implemented a quality-improvement program that later became known as Six Sigma. The methodology involved four simple but rigorous steps: 1) measuring every process and transaction, 2) analyzing each of them, 3) improving them carefully, and 4) controlling them rigorously for consistency. It was more than a set of tools, though; Motorola applied Six Sigma as a way to transform its business, a way driven by communication, training, leadership, teamwork, measurement, and a focus on customers.

In 1995, General Electric CEO Jack Welch directed the company to adopt Six Sigma as a corporate initiative, with a corporate goal to be a Six Sigma company by the year
2000. In 1997, the GE Six Sigma effort contributed $700 million in corporate benefits. In 1998, GE expected to see benefits of $1.2 billion. At that point, unpeeling the next layer of the onion requires a different set of investigative tools and a new methodology. If done well, using Six Sigma tools will allow GE to continue to reduce business costs relative to income [24, 23, 99, 33].

To date, only a handful of chemical firms have committed to the Six Sigma approach of improving business processes, but that number is rapidly increasing. Honeywell, which now includes AlliedSignal, leads the chemical industry in implementing Six Sigma. Raymond Stark, AlliedSignal’s vice president of Six Sigma and productivity, said the process improvement strategies boosted AlliedSignal’s bottom line by $500 million in 1998 and would contribute $625 million in 1999. "Once you get the momentum going, it’s a very significant force," Stark said [64].

Six Sigma is a methodical and rational approach to achieving continuous improvements in areas critical to the success of any manufacturing or service-oriented business. More and more companies are realizing that they can achieve substantial improvement by applying Six Sigma methods to improve process quality, because Six Sigma methodology requires companies to measure and analyze their business processes continuously. Six Sigma requires that companies build their businesses around a close understanding of their customers’ requirements, bringing as much discipline and focus to this external knowledge as they do to internal process-improvement efforts. Knowing that the Six Sigma goal is only 3.4 defects per million opportunities, a 99.99997% error-
free performance, the payoffs from these activities can be huge, enabling the company
to achieve quantum leaps in quality and competitiveness. Many companies today
operate around $3\sigma$, which translates into roughly 67,000 defects per million operations.
Manufacturers frequently achieve four sigma, while service firms are often at one or two
sigma.

Amazingly, to date academia has not attempted to implement Six Sigma methodology.
On the other hand, academia has used many TQM tools to measure programs’ and
students’ performance. Many colleges’ TQM models have used Deming’s PDCA cycle,
Juran’s six steps of problem-solving and Pareto principle in quality improvement,
Crosby’s zero-defects performance standards, Ishikawa’s fishbone diagram and
statistical quality tools, and other similar approaches. A general drawback for institutions
of higher education in measuring customers’ satisfaction is the lack of customer\(^3\) awareness among employees. About 11% of institutions indicate that they have full
customer awareness by all their employees [122]. Lack of quality in the culture exists
among employees in many colleges. Lack of commitment, insufficient knowledge, and
fear of failure originate largely from school management. Measurements of the
performance of a program are usually driven by the following assessment tools: exit
surveys for seniors, alumni surveys, and retention data. These are insufficient for
assessing engineering programs because they do not clarify the quality of education
students receive, much less identify and change the weakest points (e.g., the quality of
course contents, the effectiveness of course organization, instructor competence in

\(^3\) The word “customers” represents students, employers, graduate schools, community and society,
industrial advisory councils, and professional societies, as stated in Chapter 1.
transferring knowledge) in the program. This is because surveys cannot carry too many questions, and so cannot address all vital concerns.

Even though EC 2000 requires engineering colleges to commit to continuous improvement as key to successful educational programs, and the majority of engineering schools have their educational objectives defined and mapped to ABET outcomes, the problem is that the evaluation tools for most engineering colleges’ programs, including the University of Florida Computer Engineering Program and the University of Illinois Electrical and Computer Science Engineering Program, still remain on the survey level. This leaves continuous improvement on shaky ground. The University of Florida Computer Engineering Program presented its ABET 2000 report in September 2000. Three tools were used in the assessment: focus groups with students and employers, surveys, and exit interviews. The University of Florida report is considered one of the better-prepared assessment reports [34]. The University of Illinois Electrical and Computer Science Engineering Program conducted a very comprehensive survey on its students in the spring of 2000 [38]; a great deal of valuable information was gathered. Although it was a very broad outcome assessment on how well the department learns about and responds to the needs of students and other constituents, it still relied on only a single source of information: students.

On the other hand, almost every engineering college in the United States has applied TQM tools to specific courses. These measurements are usually limited to individual courses and are mainly one-time efforts. In fact, 63.5% of institutions use consultants
only occasionally [122]. The proportion of institutions that have a high level of expertise in TQM is about 25.9 percent [6, 141, 122]. One of the most popular quality-control techniques is student focus groups, which are usually audiotaped or videotaped for data collection and analysis. Another popular quality-control technique is a capstone design course. Capstone courses are designed to demonstrate that graduates have certain attributes equivalent to those required by EC 2000.

Programs are usually eager to present evaluation reports immediately and draw conclusions from them, forgetting that the data were obtained in a nonsystematic way and that the conclusions may not be very useful in the long run. The continuous quality improvement of an academic program is too complex to be built on short evaluations. There is doubt that assessment is important if a program is to be improved, but colleges need a very systematic approach for evaluating educational outcomes.

**The DMAIC⁴ Six Sigma Improvement Model**

If implemented wisely, Six Sigma can be very beneficial to improving outcomes. However, if the technique is not executed in a manner that fits the needs of the organization, there is a real danger that the actions will be counterproductive and frustrating [24]. Organizations can sometimes get so involved in “how to count defects” and report defect rates that they lose sight of the real value of Six Sigma: orchestrating process improvement and reengineering bottom-line benefits through the wise

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⁴ Define–Measure–Analyze–Improve–Control.
implementation of statistical techniques [24, 23]. A Six Sigma program needs to be orchestrated toward achieving a Smarter Six Sigma Solution\(^5\), which usually refers to a five-phase improvement cycle that has become increasingly common in Six Sigma organizations: Define–Measure–Analyze–Improve–Control, or DMAIC. The question is how to adopt this approach to meet unique challenges in the service sector, since that is the focus of this research.

**Some Guidelines for Making Six Sigma Work in Service Organizations**

A common concern of every manager and business leader is how to apply Six Sigma to his or her company. People in service or transaction-based areas are even more confused about how this supposedly manufacturing-oriented discipline will help them. According to Pande et al. [99], there are some important, understandable reasons why service-based processes often have more unexpressed opportunities for improvement than manufacturing operations, including invisible work processes, evolving workflows and procedures, lack of facts and data, and lack of a “head start.”

Pande et al. make some broad suggestions on how to make Six Sigma more effective in a service industry: “First, service organizations need to discover what is really going on. For most service organizations, starting to investigate processes is like turning up the lights. After the lights are on and the things are visible, the only way to get a really clear perspective is to get to work detailing the processes and customer requirements, and

\(^5\) Smarter Six Sigma Solution, also known as S\(^4\), is a term used by Breyfogle [24].
the issues affecting them. One of the biggest obstacles between goals and clarifying issues, measuring performance, and generating improvement in the service arena is the fact that the information is usually sketchy, and undefined. The discipline of effective project selection and problem definition is essential" [99].

The most controversial of Pande’s suggestions is not to overemphasize statistics [99]. The key reason for this is that people who are not used to technical processes and measurement are not ready for more sophisticated tools, and the data they have available is not ready for advanced analysis. Timing is everything. Fortunately, many of the problems in a service environment, especially in the early stages of Six Sigma, can be solved, with excellent results, with only occasional need for advanced statistics. Nevertheless, a number of service organizations have experienced that once people begin to use basic measurement and data-analysis methods, and see the value of the tools, they start to ask for more advanced data-gathering and analysis tools.

Dr. Mikel Harry, a Motorola alumnus who has become one of the better-known Six Sigma statistical experts, admits that he used to think “the sun rose and set on statistics” [58] but that he now recognizes that how those tools are used is more important.

Overall, it’s most important to Six Sigma improvement that people in service or manufacturing learn to ask critical questions about their processes and customers: How
do we really know that? Is there some way we can test our assumptions? What are the
data telling us? Is there a better way to do this? [99]
2.2. *Database Systems Literature Review*

Databases and database systems have become an essential component of everyday life in modern society. In the course of a day, most people come across several activities that involve some interaction with a database. For example, going to the bank to deposit or withdraw funds, making a hotel or airline reservation, using a computerized library catalog to search for a bibliographic item, and ordering a magazine subscription from a publisher all involve someone using a database. Even purchasing items from a supermarket often involves an automatic update of the store’s inventory database [40].

These interactions are examples of what may be called traditional database applications, in which most of the information that is stored and accessed is either textual or numeric. In the past few years, advances in technology have been leading to new applications of database systems. Multimedia databases now can store pictures, video clips, and sound messages. Geographic information systems can store and analyze maps, weather data, and satellite images. Data warehouses and online analytical processing systems are used in many companies to extract and analyze information from very large databases for decision-making. Real-time and active database technology is used in controlling industrial and manufacturing processes. Schools store students’ records and work. And database search techniques are being applied to the World Wide Web to improve users’ search for information as they browse through the Internet. To understand what elements of this system need to be added to
the assessment model, the main components of a database system must be understood.

**The Basics of a Database System**

A database system is basically just a computerized record-keeping system. The database itself can be regarded as a kind of electronic filing cabinet; i.e., it is a container for a collection of computerized data files. Users of the system can perform a variety of operations on files to retrieve and update information on demand. The information in question can be anything that is of significance to the individual or organization concerned, anything that is needed to assist in running the business of that individual or organization.

In the database systems world, the terms *data* and *information* must be defined. Some writers prefer to distinguish between the two, using *data* to refer to what is actually stored in the database and *information* to refer to the meaning of that data as understood by some user. This distinction is of the greatest importance in the database world.

Figure 2.5, taken from Date’s book *An Introduction to Database Systems* [33], represents a simplified picture of a multiuser database system (a multiuser system is one in which many users have access to the database at the same time). This simplified
A database system involves four major components: data, hardware\textsuperscript{6}, software, and users.

Figure 2.5. Simplified Picture of a Database System

In general, the data in the database, at least in a large system such as a college of engineering, will be both integrated\textsuperscript{7} and shared\textsuperscript{8}. Any given user will typically be concerned only with some small portion of the total database, and moreover different users’ portions will overlap in various ways.

\textsuperscript{6} For the purpose of this study it is not necessary to discuss the hardware component of a database system.

\textsuperscript{7} A database can be thought of as a unification of several otherwise distinct files, with any redundancy among those files at least partly eliminated (e.g., an EMPLOYEE file with employee names, addresses, departments, etc., and an ENROLLMENT file representing the enrollment of the employees in training courses).

\textsuperscript{8} Individual pieces of the data in the database can be shared among different users, in the sense that each user has access to the same piece of data, possibly for different purposes.
There are three broad, and somewhat overlapping, classes of users: application programmers, end users, and the database administrator. Application programmers are responsible for writing database application programs in some programming language such as C++, Visual Basic, or Java. End users interact with the system from an online workstation or terminal. A given end user can access the database via one of the online applications, or he or she can use an interface provided as an integral part of the database system software. The third class of user is the database administrator (DBA).

Before the DBA is defined, it is important to introduce the term data administrator. The data administrator is the person in the enterprise who has central responsibility for the data. Given that the data is one of the enterprise’s most valuable assets, it is imperative that there is some person at a senior management level who understands that data, and the needs of the enterprise with respect to that data. The technical person responsible for implementing the data administrator’s decisions is the database administrator. The DBA, unlike the data administrator, is an information technology (IT) professional, whose job it is to create the actual database and to implement the technical controls needed to enforce the various policy decisions made by the data administrator [33].

Between the physical database itself and the users of the system is a layer of software, known as the database management system (DBMS). All requests for access to the database are handled by the DBMS. Although the DBMS is the most important software component in the overall system, it is not the only one. Others include utilities,

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9 Enterprise is a generic term for any commercial, scientific, or technical organization.
application development tools, design aids, report writers, and the transaction manager or TP monitor. [81, 40]

**Relational Database Systems**

The designer of a database must make decisions regarding how best to take some system in the real world and model it in a database. This consists of deciding which tables to create, what columns they will contain, and the relationships among the tables. While it would be nice if this process were totally intuitive and obvious — or, even better, automated — this is simply not the case. A well-designed database takes time and effort to conceive, build, and refine [81]. Commercial systems mainly implement the relational data model. Relational database management systems (RDBMSs) today offer the client/server database architecture\(^\text{10}\) too, which is the database structure usually required for a university environment.

The relational database model is based on branches of mathematics called set theory and predicate logic. The basic idea behind the relational model is that a database consists of a series of "unordered" tables (or relations) that can be manipulated using non-procedural operations that return tables [81].

Microsoft Access is well-known implementation of the relational data model on the PC platform. It is part of an integrated set of tools for creating and managing a database on ________________

\(^{10}\) RDBMSs were initially single-user systems.
the Windows platform. Paul Litwin noted: “When compared with other database
management programs, Microsoft Access fares quite well in terms of relational fidelity.
Still, it has a long way to go before it meets all 12 rules\textsuperscript{11} completely [81].” Another very
popular and widely used commercial RDBMS is Oracle, from Oracle Corporation.

\textsuperscript{11} The relational fidelity of database programs can be compared using Codd’s 12 rules (since Codd’s
seminal paper on the relational model, the number of rules has been expanded to 300) for determining
how DBMS products conform to the relational model.
2.3. ABET Assessment Literature Review

ABET, the Accreditation Board for Engineering and Technology, may certify all U.S. engineering programs. According to the ABET Engineering Criteria 2000\textsuperscript{12}, optional accreditation criteria, engineering programs must demonstrate that their graduates are participating members of organizations, teams, and the world [4]. So from now on, 21st-century engineers must possess more than technical competence. They need to be skilled in teamwork, communications, ethics, and the evaluation of engineering problems in societal and global contexts [4].

ABET EC 2000

In response to growing needs for quality engineering education, the ABET commission took an unprecedented step in January 1994. It met for two days to explore whether ABET’s existing criteria for engineering programs should be modified [4]. The result was EC 2000. Nevertheless, ABET did not formulate EC 2000 alone. The criteria were created in cooperation with academia, industry, and 29 professional engineering societies. The new criteria were pilot-tested at assorted educational institutions, two in 1996-’97 and three more in 1997-’98. Starting in September 2001, EC 2000 became the sole set of criteria for judging all U.S. engineering programs [130]. EC 2000 requires engineering schools to be committed to four principles that challenge long-cherished assumptions:

\textsuperscript{12} The ABET’s eight EC 2000 criteria, fully presented in Appendix D, are taken from “2001–2002 Criteria for Accrediting Engineering Programs.”
• Setting educational objectives is key to successful educational programs.
• Outcome assessment is essential for evaluating how well the objectives are being met.
• So-called soft (nontechnical) skills should not be neglected.
• Continuous improvement is necessary for both the schools and their graduates.

The most important elements of ABET assessment are Program Educational Objectives (Criterion 2) and Program Outcomes and Assessment (Criterion 3), as described below.

**Program Educational Objectives**

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

a) Detailed published educational objectives that are consistent with the mission of the institution and these criteria
b) A process based on the needs of the program’s various constituencies in which the objectives are determined and periodically evaluated
c) A curriculum and processes that ensure the achievement of these objectives
d) A system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

**Program Outcomes and Assessment**

Engineering programs must demonstrate that their graduates have:

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
d) An ability to function on multidisciplinary 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 and societal context  
i) A recognition of the need for and an ability to engage in lifelong learning  
j) A knowledge of contemporary issues  
k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.  

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. Evidence that may be used includes but is not limited to student portfolios, including design projects; nationally standardized subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.  

**Accreditation on the Program Level**  

Accreditation is voluntary, and the institution must request accreditation by ABET. Educational programs rather than institutions, departments, or degrees are accredited. It is up to a particular program to ensure that it meets minimum criteria for accreditation [4]. According to the ABET 2001-2002 Accreditation Policy and Procedure Manual a program is an organized educational experience that consists of a cohesive set of courses or other educational modules sequenced so that reasonable depth is obtained in the upper-level courses. A definite stem should be obvious in the program, and,
again, depth should be reached in pursuing courses in the stem. Furthermore, the program should develop the ability to apply pertinent knowledge to the practice of the defined area of the program. A program must also involve the broadening educational objectives expected in modern postsecondary education [75].

**Elements and Requirements of the Evaluation**

An institution and its programs that are seeking accreditation need to clearly state expectations for learning and student achievement appropriate to the mission and educational objectives of the institution and program. Programs need to have academic policies related to students, such as admissions, probation, dismissal, grievances, and graduation requirements, that are fair, equitable, and published. If academic policies for the program are different from or in addition to the institution’s, those differences must be clearly stated. The criteria used by faculty to evaluate student work must be equitable, consistently applied, and clearly articulated to students, faculty, and staff [4, 116].

It is also imperative to show records of employment of graduates and, as appropriate, passage rates on nationally standardized examinations to evaluate placement and performance in terms of the goals stated for each program [4]. In order to make a qualitative evaluation of a program, it is necessary that the institution exhibit teaching materials such as course outlines and textbooks for all courses required for graduation. Sufficient examples of student work in technical, mathematics, and science courses must be available to the visiting team for the entire campus visit [4]. The examples
should show a range of grades for assignments, including homework, quizzes, examinations, drawings, laboratory reports, projects, and samples of computer usage in technical courses. Examples must also be presented to demonstrate compliance with the requirement for student competence in written and oral communications [4].

Some Experiences of Accredited Programs

Almost all engineering colleges in the United States are already engaged at some level in this evaluation. Some experiences of accredited programs are described below. Each institution has approached the subject differently, which is ABET’s main idea: to adjust assessment to the institution’s environment and needs.

The College of Engineering at Drexel University has established a new evaluation process to meet the curricular and ABET EC 2000 outcome assessment needs. This is the first time a formal, uniform, and regular course evaluation process is being implemented in the College of Engineering at Drexel. The process has been successfully implemented on the Web, and a continuous quality improvement feedback loop has been initiated [80]. The evaluators at Drexel University have acknowledged three major accomplishments in the assessment process: questions specified by the teaching faculty, Web delivery of the assessment tool to students, and faculty evaluation of courses and students. The assessment team underlined that several key challenges remain, such as expanding the process to include all engineering courses, increasing the student response rate, achieving full faculty support for the process, and finalizing the details of Web distribution of the results to all interested constituencies.
The Northern Michigan University Assessment Committee in Accomplishing Liberal Studies Outcomes is interested in monitoring students’ progress in achieving the desired learning outcomes for liberal studies, in addition to measuring results upon (or nearing) completion of studies [96]. The committee believes the liberal studies program is essential for a quality education program based on the principles that: a) well-educated persons need to know more than can be learned from study within specific areas of concentration alone; and b) learning as a life-long process can be effectively acknowledged and enhanced within a liberal education environment.

As part of the continuing review of its curriculum, the Civil Engineering Department at Lamar University distributed a survey instrument to three groups: engineering undergraduates, graduate students, and practitioners. Koehn elaborated on the results:

The questionnaire listed the 21 subject areas in the civil engineering program criteria and requested that respondents indicate the level at which they should be included in the curriculum. The findings indicate that over 50% of respondents believe that four subjects should be incorporated into the program at a high level. They include: structural engineering, hydraulics/hydrology/water resources, engineering design, and mathematics through calculus and differential equations.

These results suggest that all three groups strongly endorse the traditional technical aspects of engineering. In contrast, one subject, general chemistry, received a low rating. This suggests that undergraduates may not have developed the background to recognize the importance and need for non-technical subjects. These beliefs may change, however, as they take more courses to complete their program and/or gain additional practical experience. In fact, roughly 40% of the responding undergraduates require at least one additional semester of coursework to complete their degree requirements. These courses cover many of the professional practice issues specified by the criteria. Overall, 81% of the subject areas included in the ABET recommended civil engineering program criteria are rated by both students and practitioners with a composite score of 3.1. This may be interpreted as strong support for the Engineering Criteria 2000 program requirements [75].
2.4. Application of the Model

The College of Engineering of the University of Cincinnati must prove itself to be an institution offering the highest level of education. To do so, the college needs to have a well-developed assessment model based on continuous quality improvement. The implementation of a systematic assessment model requires a step-by-step approach with the full involvement of the college’s top administrators and faculty. The University of Cincinnati, College of Engineering has nine programs in six departments; the assessment is done at the program level. Each engineering program has a unique set of objectives for its graduates, and each requires well-defined assessment tools.

However, all nine engineering programs need to meet ABET EC 2000 requirements. In addition, all programs have a similar educational setup: Students must experience six co-op quarters, and all programs have similar desired educational outcomes. Given all these factors, the generic assessment model is designed in such a way that it can be successfully adopted as a template for an assessment process in each program of the college. Application of the model was tested on the Industrial and Manufacturing Engineering (IME) program.
Chapter 3. Methodology

3.1. General Approach to the Model

To be accredited by ABET EC 2000, and to stay competitive in the academic environment, an engineering college must develop an assessment model that will ensure continuous quality improvement of its educational programs. At the same time, the college must not focus solely on satisfying EC 2000 requirements. Soon, most engineering colleges in the United States will have proven to ABET that they have a system of continuous improvement in place, and soon, the ABET accreditation committee will no longer set the standards for quality. Satisfied customers, such as students, parents, employers, graduate schools, community and society, and professional societies, will be the ones to establish quality requirements. “In fact, customer satisfaction is regarded as the only relevant objective for ensuring stable and continuously increasing business” [99]. To continuously improve the quality of service, which is a fundamental goal in a total quality setting, it is necessary to continuous improve the system. A strategic plan should be developed with respect to each program’s long-term goals. Indeed, adding value to the quality in education as a long-term goal will provide programs, and a college as a whole, with sustainable competitive advantage in the marketplace.

The best way to attack this challenge is to apply Six Sigma methodology in improving the service of the system. Six Sigma methodology differs substantially from other quality
initiatives such as Continuous Process Improvement and Total Quality Management, which focus on quality for the sake of perfection, not for the customers’ sake, ignoring incremental improvements. In contrast, Six Sigma focuses on delivering the same level of quality with respect to cost reduction and sustainable financial advantage. It requires commitment, a high level of training in both the philosophy and the methods, and a strong vision of where an organization can be. Six Sigma also requires top-down commands.

One of the structural changes, for example, is that employees trained in the Six Sigma ways take on new roles such as “project champion” or “black belt.” Also, Six Sigma thinking may be applied to any business process, introducing the term \textit{defect-per-million opportunity} (DPMO). Once the administration/management defines what is most relevant to the customers, which in academia means, for example, having graduates with strong communications skills, then the focus transfers to activities that most affect the school’s ability to act on a request quickly and measure those activities. But the task is far from simple. Every decision made will affect the system (in this case an educational program). The management must have a robust quality process improvement in place.

This means that even before the measurement phase is set, a systematic data collection plan should be implemented. Data collection provides Six Sigma management with the wide-ranging information necessary for a meaningful analysis.
Often, a robust database is implied as an integral part of the Six Sigma initiative. The general approach to the assessment can be broken into the following steps [24]:

1. Identify core processes and key customers.
2. Define customer requirements.
4. Prioritize, analyze, and implement improvements.
5. Expand and integrate the Six Sigma system.

The Six Sigma methodology was applied to develop the assessment model described in this project. Like any other Six Sigma project, this consists of five basic activities: define, measure, analyze, improve, and control, wrapped up into the process of continuous quality improvement, as illustrated in Figure 3.1.

Figure 3.1. The Six Sigma Road Map
There is no one path to Six Sigma improvement, however. The assessment plan for an educational program will undergo several adjustments along the way. These steps, presented in Figure 3.1 above, will change depending on the nature of the system (in this case an engineering program). The program should be driven by establishing goals, by defining measurable program objectives, by establishing an effective process, and by determining program outcomes that result from achieving program objectives. Elements of an educational system (program) are illustrated in Figure 3.2.

Figure 3.2. A Program General Process Map
From the EC 2000 perspective and the experience of the programs accredited by ABET, the driving force behind a program strategic plan is the program’s primary customer, the student. The other key customers could include parents, graduate schools, community and society, employers, and professional societies. Customers will provide the program with the necessary qualifications required for the program's graduates, with desired standards for the program, with important trends in business, and with values that guide performance and governance. Also, very important elements of each engineering program are its mission and its goals, which reflect the mission and the vision of its university as well as of the college of engineering.

The key to the model is assessment, the process of evaluation leading to the improvement of quality in performing the program's long-term goals, or mission. Assessment of how well the mission is being accomplished provides a stimulus for continuous quality improvement of an engineering program. Thus, the objective of assessment is to measure outcomes and facilitate continuous improvement.
3.2. Mechanism of the Generic Assessment Model

The real value of Six Sigma is in orchestrating process improvement and reengineering bottom-line benefits through a wise implementation of statistical techniques [23, 24]. A Six Sigma program needs to be orchestrated toward achieving a “Smarter Six Sigma Solution,” which usually refers to a five-phase improvement cycle that has become increasingly common in Six Sigma organizations: Define-Measure-Analyze-Improve-Control, or DMAIC.

This thesis answers the question of how to adapt this approach to meet the unique challenges in the service sector. DMAIC applied to engineering education settings should be a systematic assessment of every course in the program, followed by an assessment of the program and of the college as a whole.

However, it is important to note that application of Six Sigma in academia does not mean achievement of the Six Sigma level of quality, which is virtually defect-free operation. It is rather a methodology that uses extremely rigorous data gathering and statistical analysis to identify sources of errors and ways to eliminate them.

Six Sigma applied to an educational setting is best described through the following elements:

- Variation control through all levels of an educational organization
- Student focus (customer specification limits)
- Assessment based on data
- Continuous quality improvement
- A new administration initiative based on strategic plans
- Faculty participation throughout the process

The results of assessment for each DMAIC cycle of an engineering program are documented to ensure continuous improvement. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program are being measured.

The Industrial and Manufacturing Engineering (IME) Program of the College of Engineering at the University of Cincinnati is used as a case example for a preliminary test of the generic model.

**Program-Level Assessment**

Six Sigma is a fluid methodology that works at any level of the organization if long-term improvements are to be made. Almost every organization can be broken down into three basic levels: high, middle, and low [58]. The higher level (the college) is the corporate level, where executives use Six Sigma to ensure the organization’s long-term capability. The middle (program) and low (classroom) levels are the operation and process levels, respectively, where managers use Six Sigma to reduce variation and meet operational goals (college objectives and learning outcomes) leading to improved
customer satisfaction.

However, in education, the most important process to a customer is the process that occurs in an educational program. Educational programs, rather than institutions or degrees, are assessed for quality. An engineering program is a complete plan of study in a specific field. It ensures that every course within the program meets the rigorous academic standards for both content and faculty expertise. A definite pattern should be obvious in the program, and, again, depth should be reached as courses progress [75]. Furthermore, the program has the ability to apply relevant knowledge to the practice of the defined field. The program’s outcomes result from achieving its goals and objectives. Therefore, the academic program is that common denominator for the evaluation of students’ performance and ultimate ability to adjust to the working environment.

Core Processes and Key Customers

Although it is not included in the five phases of Six Sigma methodology, identification of key processes and key customers of the organization is in fact the starting point of this model\(^\text{13}\). Essential processes behind an engineering education program strategic plan are broken down into two parts: coursework and professional practice with an actual employer. Also, the driving forces of the program are the primary customer — the student — and the program’s external customers — parents, employers, graduate

\(^{13}\) Some authors in the area of Six Sigma strategy even recognize it as the actual first phase of Six Sigma methodology.
schools, community and society, and professional societies. Many college administrators are not sensitive to outside customers and the impact they may have on the quality of education. That is one reason they are not able to continuously improve quality in their institutions. This model takes into consideration the external customers of a college of engineering.

**Definition Phase: Defining Customer Requirements and Program Objectives**

In this phase it is important to understand what customers really want – and how their needs, requirements, and attitudes change over time [99]. Making it a continuous effort may be critical to business success. An engineering program should be driven by:

- Establishing goals
- Defining measurable program objectives
- Establishing an effective process
- Determining program outcomes that result from achieving program objectives.

The first step before an assessor starts the process is to define program objectives and design outcomes. The objectives of the program should broadly reflect the needs of both the students and the community. The University of Cincinnati’s IME Program objectives:

1. Provide students with knowledge of mathematical, physical and social sciences; economic, operational, and engineering analyses; and the principles and techniques of engineering design.
2. Provide students with a solid background in principles and methods of basic manufacturing processes, advanced manufacturing systems, and the applications of control theory and digital system techniques in manufacturing (processes).

3. Prepare students to design, install, and improve complex systems and processes that integrate people, materials, and equipment, placing unique demands for breadth of preparation upon industrial engineers.

4. Emphasize the principles of probability, statistical inference, quality control and reliability, and operations research and their applications in engineering; the utilization of human resources; productivity improvement; and interdisciplinary topics such as biomechanics, engineering economics, and numerical methods.

5. Prepare students for professional practice and further study in the area of industrial engineering, emphasizing students’ creativity, innovation, teamwork, and leadership roles in industry by propagating these ideas into project topics.

The evaluation of how well objectives are being met depends on the program outcome assessment. Since most engineering colleges seek ABET accreditation and are therefore obligated to satisfy the 11 ABET educational outcomes requirements, it is essential that ABET outcomes be incorporated into this model as program outcomes. The list of program outcomes could, however, be expanded with respect to the program’s educational goals. The IME program at the University of Cincinnati will demonstrate that its graduates meet all 11 ABET outcomes:

a. Ability to apply knowledge of mathematics, science, and engineering
b. Ability to design and conduct experiments, as well as to analyze and interpret data

c. Ability to design a system, component, or process to meet desired needs

d. Ability to function on multidisciplinary teams

e. Ability to identify, formulate, and solve engineering problems

f. Understanding of professional and ethical responsibility

g. Ability to communicate effectively

h. Broad education necessary to understand the impact of engineering solutions in a global and societal context

i. Recognition of the need for and the ability to engage in life-long learning

j. Knowledge of contemporary issues

k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

The correlation between the IME program’s educational objectives and outcomes is presented in Table 3.1. Each educational objective meets several program outcomes. The correlation is indicated by “✓”.

In the IME model program outcomes are identical to ABET outcomes. However, program outcomes must not be limited to these 11 ABET requirements, but should reflect specific goals of regional programs. Realizing the relationship between a program’s educational objectives and the program’s outcomes is important to achieve this model’s final objective — that is, to facilitate continuous improvement.
Table 3.1. Correlation Between Educational Program Objectives and Program Outcomes

<table>
<thead>
<tr>
<th>IME Program Educational Objective</th>
<th>ABET Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provide students with knowledge of mathematical, physical, and social sciences; economic, operational, and engineering analyses; and the principles and techniques of engineering design</td>
<td>✓</td>
</tr>
<tr>
<td>2. Provide students with a solid background in principles and methods of basic manufacturing processes, advanced manufacturing systems, and the applications of control theory and digital system techniques in manufacturing (processes)</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>3. Prepare students to design, install, and improve complex systems and processes that integrate people, materials, and equipment, placing unique demands for breadth of preparation upon industrial engineers</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>4. Emphasize the principles of probability, statistical inference, quality control and reliability, and operations research and their applications in engineering; the utilization of human resources; productivity improvement; and interdisciplinary topics such as biomechanics, engineering economics, and numerical methods</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>5. Prepare students for professional practice and further study in the area of industrial engineering, emphasizing students’ creativity, innovation, teamwork, and leadership roles in industry by propagating these ideas into project topics</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

While students’ coursework should be determined by the program objectives, not every course needs to satisfy all program objectives. However, the objectives need to be executed through the program curriculum. The IME courses that meet relevant IME program objectives are shown in Table 3.2. The model requires that the assessment of the program be focused on the last three years of students’ education (towards a bachelor’s degree). This is possible because an engineering program curriculum is
always structured in such a way that the basic engineering techniques taught during the first two years are re-evaluated later in advanced courses.

Table 3.2. IME Program Courses That Meet Relevant IME Program Objectives

<table>
<thead>
<tr>
<th>Course</th>
<th>Appropriate IME Program Educational Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year III</td>
</tr>
<tr>
<td>MATH276 Matrix Methods</td>
<td>1</td>
</tr>
<tr>
<td>INDS322 Numerical Methods</td>
<td>3</td>
</tr>
<tr>
<td>INDS341 Eng. Stat. Meth. II</td>
<td>4</td>
</tr>
<tr>
<td>INDS354 Manuf. Process. I</td>
<td>2, 3, 5</td>
</tr>
<tr>
<td>INDS355 Manuf. Process. II</td>
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<tr>
<td>ENFD371 Elec. Crct. Anal.</td>
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<td>ENFD383 Basic Fluid Mech.</td>
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<tr>
<td>ENFD385 Basic Heat Trans.</td>
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</tr>
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<td>Year IV</td>
</tr>
<tr>
<td>INDS438 Ergonomics</td>
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<tr>
<td>INDS440 Work Measurement</td>
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</tr>
<tr>
<td>INDS453 Operations Rsch. I</td>
<td>1, 2</td>
</tr>
<tr>
<td>INDS454 Operations Rsch. II</td>
<td>1, 2, 3, 4, 5</td>
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<tr>
<td>MINE451 Engr. Economy</td>
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</tr>
<tr>
<td>INDS470 Lab. for IE</td>
<td>1, 2</td>
</tr>
<tr>
<td>INDS475 Manufac. Controls</td>
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</tr>
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<td>INDS511 Quality Control</td>
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<td>INDS552 Facilities Design</td>
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<td>INDS555 Simulation</td>
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<tr>
<td>INDS556 Prod. Plan &amp; Con.</td>
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</tr>
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<td>MINE586 Clinic II</td>
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<tr>
<td>MINE587 Clinic III</td>
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<tr>
<td>MIE Elec. 1</td>
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<tr>
<td>MIE Elec. 2</td>
<td>1, 2, 3, 4, 5</td>
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<tr>
<td>MIE Elec. 3</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>MIE Elec. 4</td>
<td>1, 2, 3, 4, 5</td>
</tr>
</tbody>
</table>

Measurement Phase: Measuring Current Performance

This phase is concerned with gathering enough data to compare business core processes. In any Six Sigma initiative other than training, measurement is the biggest task for many business systems. It can take a lot of time to collect enough evidence to
perform valid analysis. Measuring program performance also requires a performance tracking system that is capable of “cutting” through data in many different ways. In other words, it is important to develop such measuring techniques so that assessors are able to hierarchically pool data to the appropriate business levels. The measurement phase must answer two fundamental questions: what to measure, and how to measure it.

**Designing the Assessment Tools**

Multiple assessment tools must be developed and implemented to validate the achievement of the program outcomes. It is essential for a quality assessment to check whether the students have acquired content knowledge, whether they can construct an argument, operate machinery correctly, or be decision-makers in a major project [4]. To collect this kind of information, colleges use different assessment tools. One of the most popular and most effective is the review of a student’s portfolio — a collection of a student’s work, including samples compiled over time. On the other hand, techniques like surveys, interviews, and third-party reports provide assessors with valuable information where it is more difficult, though not impossible, to assess students — on such attributes as “achievement of self-awareness” and “independent thinking.” Also, surveys can provide a program with access to individuals who otherwise would be difficult to include in the assessment efforts (e.g., alumni, parents, and employers), to gain an insight into standards a program needs to have and information on important trends in business.
To make the assessment process as simple as possible, which is very important at the beginning, the first program assessment cycle is based on four types of assessment tools: portfolios, surveys, exit interviews, and student co-op performance data. Additional assessment tools should be considered as the assessment progresses.

**Portfolio**

To capture most of the educational program outcomes, the portfolio material is collected considering eight educational goals. The coursework is broken down into eight educational portfolio aspects, which allow educators to simultaneously monitor different skills that students should have mastered as college graduates.

- **Portfolio Aspect I:** Skills in Calculus, Physics, Chemistry and Electronics
- **Portfolio Aspect II:** Writing and Communication Skills
- **Portfolio Aspect III:** Engineering Design Skills
- **Portfolio Aspect IV:** Information Systems and Technology Skills
- **Portfolio Aspect V:** Engineering Measurement Skills
- **Portfolio Aspect VI:** Management Skills
- **Portfolio Aspect VII:** Economics Skills
- **Portfolio Aspect VIII:** Skills in Engineering Science

A faculty member uses a variety of criteria when assigning a grade to a student for a particular portfolio aspect.

**Portfolio Aspect I: Skills in Calculus, Physics, Chemistry, and Electronics**

This area of science is the foundation for all basic and advanced engineering courses. Therefore, when assessing students' work in other engineering courses, professors must review their performance in mathematical analysis and
methodology, calculus, physics, and chemistry. There are several types of assignments that have been used in the past and that should be used in the future, including homework, class presentations, laboratory experiments, written summaries of texts and outside readings, and quizzes and exams.

Portfolio Aspect II: Writing and Communication Skills

Writing is a central intellectual tool for lifelong learning. It provides a uniquely valuable mode of learning, and if ignored, as it is currently in many engineering courses, students will be deprived of perhaps the most important skill they could gain during their collegiate careers [67]. By assessing students’ understanding through writing assignments, educators can precisely and efficiently identify and correct errors in students’ thinking. The writing component in team projects may be the most important factor in ensuring effective collaboration.

Portfolio Aspect III: Engineering Design Skills

Engineering design is an iterative process of modeling and optimization to find the best technological solution within given constraints [136]. Most engineering courses are based on various types of design projects that are real engineering work; these projects should be collected for a student’s portfolio. Faculty members measure critical thinking abilities, as evidenced by completion of the design, meeting design goals, staying within design constraints, completion of analytical results, analysis of results, view of predictions inside the limits of the
project’s topic, written presentations and essays, and oral presentations of process and results.

Portfolio Aspect IV: Information Systems and Technology Skills

Knowledge of the impact and limitations of information systems is essential to students’ effective professional development. Moreover, today’s engineers spend the vast majority of their time simulating their designs. Students access, generate, process, and transfer information using appropriate computer techniques. A portfolio should hold a collection of assignments that clearly show a student’s ability to use information and various software packages and programs in designing a model.

Portfolio Aspect V: Engineering Measurement Skills

Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data. For portfolios, professors should create assignments or projects that require students to, for example, apply the conceptual foundation of limits, measure the area under the curve, measure rate of change, perform inverse variation, or apply the slope of a tangent line to authentic problems in mathematics and other disciplines.
Portfolio Aspect VI: Management Skills

A college of engineering trains emerging engineering professionals in more than the technical and scientific aspects of the profession. An educational experience should incorporate business intelligence, practices, and awareness, including some understanding of marketing, economics, and organizational management and their interaction among themselves and with the engineering process. Assignments are typically case studies that involve real-world management problems.

Portfolio Aspect VII: Economics Skills

Engineers are the principal decision-makers in manufacturing, construction, and service industries. They are the ones who set the constraints in a firm, and they are the ones who can expand those constraints. Colleges need to offer courses that will train engineers to make the most cost-effective decisions. Faculty should make assignments that include this aspect of real-life problems whenever appropriate.

Portfolio Aspect VIII: Skills in Engineering Science

An engineer must have a working knowledge of basic science and engineering science to begin designing a device. The primary objective of engineering science is to create a bridge from the natural sciences and mathematics to the practice of engineering [4]. This skill should be assessed through projects that require multidisciplinary problem-solving.
Each course in an engineering program may be “inspected” from the appropriate portfolio aspects and the evidence collected and stored for future analysis. The correlation developed between IME courses and the eight portfolio aspects is shown in Table 3.3.

The way the portfolio assessment works is best explained with an example. When a student takes INDS555, a simulation course, he or she is assigned two comprehensive projects. Typically, the professor grades the student’s work based on the projects’ objectives, and at the end of the quarter/semester the student receives one grade. In the program assessment model, this system is still in place for most of the classes in the program curriculum. However, around 10% of the students (no fewer than five) in INDS555 will be graded and assessed in more detail, and their work will be collected for analysis and program assessment. These students will undergo the portfolio assessment: When grading a student’s project, the professor will assign him or her different grades for math skills, writing skills, engineering design skills, information technology skills, management skills, economics skills, and skills in engineering science. The correlation is indicated in Table 3.3.

Breaking down coursework into both the educational aspects and the eight portfolio aspects allows educators to simultaneously monitor different skills students should master. Assessing students’ achievements this way highlights potential problems in education, and may alter the outcomes of a program.
Table 3.3. IME Program Courses and Corresponding Portfolio Aspects

<table>
<thead>
<tr>
<th>Course</th>
<th>Portfolio Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year III</strong></td>
<td></td>
</tr>
<tr>
<td>MATH276 Matrix Methods</td>
<td>I</td>
</tr>
<tr>
<td>INDS322 Numerical Methods</td>
<td>I III IV V IVIII</td>
</tr>
<tr>
<td>MINE340 Eng. Stat. Meth.</td>
<td>1 III IV V IVIII</td>
</tr>
<tr>
<td>INDS341 Eng. Stat. Meth. II</td>
<td>I III IV V IVIII</td>
</tr>
<tr>
<td>INDS354 Manuf. Process. I</td>
<td>I III IV V IVIII</td>
</tr>
<tr>
<td>INDS355 Manuf. Process. II</td>
<td>I II III IV V VII</td>
</tr>
<tr>
<td>ENFD383 Basic Fluid Mech.</td>
<td>I III IV V IVIII</td>
</tr>
<tr>
<td>ENFD385 Basic Heat Trans.</td>
<td>I III IV V IVIII</td>
</tr>
<tr>
<td><strong>Year IV</strong></td>
<td></td>
</tr>
<tr>
<td>INDS438 Ergonomics</td>
<td>II III IV V VIIIV</td>
</tr>
<tr>
<td>INDS440 Work Measurement</td>
<td>I II III IV V VI</td>
</tr>
<tr>
<td>MINE451 Engr. Economy</td>
<td>I II IV V VI VII</td>
</tr>
<tr>
<td>INDS453 Operations Rsch. I</td>
<td>I II V IVIII</td>
</tr>
<tr>
<td>INDS454 Operations Rsch. II</td>
<td>I II IV V IVIII</td>
</tr>
<tr>
<td>INDS470 Lab. for IE</td>
<td>I II V IVIII</td>
</tr>
<tr>
<td>INDS475 Manufac. Controls</td>
<td>I II III IV V IVIII</td>
</tr>
<tr>
<td><strong>Year V</strong></td>
<td></td>
</tr>
<tr>
<td>INDS411 Quality Control</td>
<td>I IV VI VII VIII</td>
</tr>
<tr>
<td>INDS452 Facilities Design</td>
<td>I II III IV V VII</td>
</tr>
<tr>
<td>INDS555 Simulation</td>
<td>I II III IV VI VII</td>
</tr>
<tr>
<td>INDS556 Prod. Plan &amp; Con.</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MINE585 Clinic I</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MINE586 Clinic II</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MINE587 Clinic III</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MIE Elec. 1</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MIE Elec. 2</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MIE Elec. 3</td>
<td>I II III IV V VI VII</td>
</tr>
<tr>
<td>MIE Elec. 4</td>
<td>I II III IV V VI VII</td>
</tr>
</tbody>
</table>

The portfolio course assessment consists of four tasks:

- Recruiting student volunteers (the sample),
- Collecting evidence and compiling portfolios,
- Maintaining and analyzing evidence, and
- Holding a series of workshops to review portfolio contents and make curricular decisions.
Considering that this project is not a priority for the students, assessors must always make sure that students do not drop out of the process.

**Surveys**

Most assessment experts agree that no single instrument provides an adequate measure and that the assessors need to use several assessment techniques simultaneously [54]. Each survey provides specific questions depending on the audience surveyed. Questions include individual perceptions of the quality of specific courses and activities, faculty evaluations, relationships with industry, and more general questions surveying the overall impact. Also, the surveys ask for comments and suggestions for improvement.

To capture areas of learning that might be difficult or costly to assess more directly, different types of surveys are designed. Four surveys were developed to support the assessment process in the IME program: the Co-op Employer Survey, the Co-op Student Survey, the Student Exit Survey, and the Alumni Survey. The IME program also conducted student exit interviews required by the College of Engineering at the University of Cincinnati. The questions were developed in such a way that they directly correspond to the 11 program outcomes.
The Co-op Employer Survey is an evaluation of students’ co-op performance.

**CO-OP EMPLOYER SURVEY**
(ASSESSMENT OF STUDENT’S PROFESSIONAL PRACTICE)

<table>
<thead>
<tr>
<th>Unsatisfactory</th>
<th>Poor</th>
<th>Satisfactory</th>
<th>Good</th>
<th>Excellent</th>
</tr>
</thead>
</table>

No:
1. Student applies knowledge of mathematics, science, and engineering.
2. Student communicates well (writes clearly and concisely, speaks effectively and clearly).
3. Student evaluates situations effectively.
4. Student solves problems/makes decisions.
5. Student exhibits a professional attitude toward work assigned.
6. Student demonstrates original and creative thinking.
7. Student applies classroom learning to work situations.
8. Student assumes responsibility and is accountable for actions.
9. Student shows initiative.
10. Student demonstrates a positive attitude toward change.
11. Student understands and contributes to the organizational goals.
12. Student functions well on multidisciplinary teams.
13. Student possesses honesty, integrity, and personal ethics.
14. Student uses technology, tools, instruments, and information.
15. Student understands complex systems and their interrelationships.
16. Student understands the technology of the discipline.
17. Student understands and works within the culture of the group.
18. Student respects diversity.
19. Student recognizes the political and social implications of actions.

The co-op Student Survey is an evaluation of students’ co-op experience.

**CO-OP STUDENT SURVEY**
(ASSESSMENT OF PROFESSIONAL PRACTICE)

<table>
<thead>
<tr>
<th>Never</th>
<th>Occasionally</th>
<th>Often</th>
<th>Very Often</th>
<th>Always</th>
</tr>
</thead>
</table>

No:
1. I have been given the opportunity to apply knowledge of mathematics, science, and engineering.
2. I have been given the opportunity to do effective presentations, to write clearly and concisely, and speak effectively.
3. I have been given the opportunity to evaluate situations effectively.
4. I have been given the opportunity to solve problems/make decisions.
5. I have been given the opportunity to show a professional attitude toward work assigned.
6. I have been given the opportunity to demonstrate original and creative thinking.
7. I have increased my understanding of responsibilities.
8. I have been given the opportunity to show the initiative.
9. I have been given the opportunity to work in multidisciplinary teams.
10. I have shown my professionalism (honesty, integrity, and personal ethics).
11. I have given the opportunity to use technology of my field, tools, instruments, and information.
12. I have understood complex systems and their interrelationships at my co-op assignments.
13. I have understood the technology of the discipline.
14. I have understood and worked within the culture of the group.
15. My co-op assignments have helped me to increase my strengths and shorten my weaknesses.
16. My co-op assignments have increased my understanding of organizational culture and practices.
17. I respect diversity.
18. I recognize the political and social implications of actions.
19. I have increased my academic motivation.

The Senior Student Exit Survey is an evaluation of students’ overall experience with the IME program and the University of Cincinnati.

**SENIOR STUDENT EXIT SURVEY**  
**(ASSESSMENT OF IME ACADEMIC PROGRAM)**

**No:**
1. Are you supported by any scholarship/assistantship?
2. Do you work while attending UC?

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>
3. Overall, I am satisfied with the educational experience at UC.
4. The program has provided me with a solid foundation in math, computer skills, and engineering.
5. I am able to understand mathematical/physics concepts.
6. The program contact challenged my depth of knowledge in the subject and analytical skills.
7. There was sufficient emphasis on real-world projects.
8. I have gained team-building and leadership skills.
9. I have built self-confidence in expressing my ideas.
10. I have built speaking and writing skills.
11. I have built entrepreneurship abilities.
12. I possess knowledge of contemporary issues and an understanding of ethical responsibility.

<table>
<thead>
<tr>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Often</th>
<th>Always</th>
</tr>
</thead>
</table>
13. I have completed a project or a paper that integrated ideas from several sources.
14. I have applied a concept or technique learned in class.
15. I have worked on an assignment that involved the use of a modern technology.
16. I have worked on a team project from concept to implementation, including a defense.
17. I have tried to explain a method or a theory to another person.
18. My professors formally monitored and assessed my competence in their courses related to concepts from other mathematics, science, or engineering courses.
19. In my assignments I used industry/professional documentation standards.
20. I have had opportunity to learn about diverse cultures and people.
21. I was satisfied with the quality of instruction in my major field.
22. I was satisfied with the quality of instruction outside my major field.
23. I was satisfied with the interaction with faculty outside the classroom.

Not at all  Little  Somewhat  Mostly  Very

24. How well did your University of Cincinnati experience prepare you for:
   a. Graduate school?
   b. Your future career?
   c. Everyday life?
   d. Contributing to society?
   e. Lifelong learning?

The Alumni Survey is an evaluation of the IME program by students who graduated from the University of Cincinnati two and five years ago. This is a very important survey for assessors to learn what the external customer needs from the IME program.

ALUMNI SURVEY
(ASSESSMENT OF IME ACADEMIC PROGRAM)

No:
1. What is your undergraduate major (engineering program)?
2. When did you graduate from UC?
3. What is your company name?
4. What is your position (current work) at the company?
   o Design  o Manufacturing
   o Research and Development  o Sales/Marketing
   o Management  o Graduate School
   o Environmental  o Unemployed_______ (Specify)
   o Other _________ (Field)
5. The program provided students with an education that allows them to develop and understand physical mechanisms, chemical science quantitative analysis, and material behavior that affect the design, performance and operation of constructed facilities.

6. The program enhanced students’ creativity and critical thinking ability, by exposing them to open-ended engineering problems and by engaging them in synthesis (“design”) activities at various stages of their learning process.

7. The program provided students with an education that allows them to understand the interaction between physical and social systems.

8. The program provided students with an appreciation for the value of continuing professional development in maintaining their professional expertise.

9. The program provided students with the multidisciplinary education necessary for addressing the complex problems of physical and social systems.

10. The program provided students with an education that allows them to be creative and synthesize in the contexts of design such that they can effectively participate in planning, design, design construction, and management within the discipline.

11. The program increased students’ awareness of contemporary global, societal, ethical, and professional issues in the practice of engineering.

12. The program exposed students to teamwork and developed the students’ ability to communicate effectively through both writing and public speaking.

13. The program coordinated the laboratory experience with the rest of the students’ program.

14. The program provided students with the preparation necessary for successful graduate work in the discipline.

Portfolio aspects and all survey questions were carefully developed so that they can be used as a direct link between the students’ coursework and professional practice and the program’s learning outcomes. The relationship between assessment tools, the surveys and the portfolio aspects, and the IME program outcomes is specified in Table 3.4.

The model is designed in such a way that collected data reflects the needs, expectations, and satisfaction or dissatisfaction levels of the students, alumni, and employers. In Table 3.4, for example, IME program outcome (a) (students’ ability to
apply knowledge of mathematics, science, and engineering) is assessed by questions 5, 6, and 19 of the student exit survey; question 5 of the alumni survey; question 1 of the employer co-op survey; question 1 of the student co-op survey; and portfolio aspects I and VIII. Each of the listed survey tools will control the final value of program outcome (a) by a certain percentage (see Figure 3.5).

<table>
<thead>
<tr>
<th>IME Program Outcomes</th>
<th>Student Exit Survey</th>
<th>Alumni Survey</th>
<th>Employer Co-op Survey</th>
<th>Student Co-op Survey</th>
<th>Portfolio Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>5, 6, 19</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>I, VIII</td>
</tr>
<tr>
<td>b</td>
<td>15, 20</td>
<td>6</td>
<td>3, 11</td>
<td>3</td>
<td>V</td>
</tr>
<tr>
<td>c</td>
<td>8, 12</td>
<td>6</td>
<td>4, 6, 7</td>
<td>4, 6</td>
<td>III, VIII</td>
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<td>d</td>
<td>9, 17</td>
<td>12</td>
<td>9, 12</td>
<td>8, 9, 14</td>
<td>IV, VIII</td>
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<td>7, 12</td>
<td>10, 14</td>
<td>7, 15</td>
<td>12</td>
<td>III, VIII</td>
</tr>
<tr>
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<td>5</td>
<td>5, 8, 13</td>
<td>5, 7, 10</td>
<td>VI</td>
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<tr>
<td>h</td>
<td>25, 7</td>
<td>16, 17, 19</td>
<td>12, 13, 16, 18, 19</td>
<td>VIII, VI</td>
<td></td>
</tr>
<tr>
<td>i</td>
<td>21, 9</td>
<td>9</td>
<td>9, 10, 17, 19</td>
<td>8, 15, 16, 18</td>
<td></td>
</tr>
<tr>
<td>j</td>
<td>13, 11</td>
<td>11, 18, 19</td>
<td>14, 17, 18</td>
<td>VI, VII</td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>14, 16</td>
<td>7, 10, 14</td>
<td>11</td>
<td>IV, V</td>
<td></td>
</tr>
</tbody>
</table>

Selecting the right tools in order to get good input on customers’ needs and requirements may be the most challenging aspect of the Six Sigma approach. However, the assessment of an engineering program is an even more challenging assignment. The amount of data that must be processed is substantial. In addition, the results of the data processing must be available for analysis by the end of each academic year.

*Map of the Database Structure*

Getting good customer input on a program’s needs and requirements is a very delicate task. It is not easy to develop or improve systems and strategies devoted to ongoing
data gathering. The database process itself is a rather complicated function of many variables that affect the final outputs. Changes or variables in the inputs and the process of a database will largely determine how the final results turn out. Figure 3.3 is a simplified illustration of this. The function \( f(X) = Y \) represents a model of an organization as seen from the process flow perspective. The X’s that appear in the input and process flow are indicators of change or performance. The Y’s represent measures of the program’s performance. The formula \( f(X) = Y \) is a mathematical way of showing that changes or variables in the inputs and process of the database will largely determine how the final result turn out.

Figure 3.3. Organization of the Process in a Database

A robust database system is an effective, very fast, systematic, and relatively inexpensive way of collecting and processing a large amount of data. Also, the database system provides strategically grouped, filtered, and tabulated data in the form of fairly simple reports. Several data sources, which have been described previously, are valid inputs for the performance measurement system (i.e., the database): students’
portfolios, co-op employer surveys, co-op student surveys, student exit surveys, and alumni surveys. The data is collected online (see Figure 3.5 on page 73). In this way the data inputs are fast, and the data is most accurate and most recent.

Figure 3.4. Online Data Collecting

Collection and processing of the results from the surveys and students’ portfolios are handled by a database tabular structure. Different data analyses need to be assembled to answer how well the program is delivering on its goals (program outcomes) today, and how likely it is to do so in the future. This specific database design is developed very carefully, starting with the data analysis because of its influence on the database design. There are two types of data used in the model: numerical and categorical, so-called “hard” data and “soft” data.
Computer systems have traditionally been limited to storing hard data, which are verifiable but are only a part of the data that should be included in this assessment process. Many soft data are very relevant to the process, too. The soft data are unquantifiable, such as students’ ability to function in multidisciplinary teams, or a student’s achievement of self-awareness. These data are captured by the surveys. In each survey the value of the data reads as follows: Unsatisfactory = 1; Poor = 2; Satisfactory = 3; Good = 4; Excellent = 5. This way, a good part of the soft data will be expressed in numerical form, which is a very important objective of the model. To be truly effective, a model that supports assessment in education must be able to handle soft data. The significance of having soft data measured is even greater, knowing that soft data represent almost 50% of the significant information. Also, all portfolio input data (the grades) are numerical in range from 1 to 5, where 5 is the maximum grade. This simplifies the measurement system. Figure 3.5 is a graphical plan of a generic approach to the assessment process.

The first row in Figure 3.5 represents sources that provide input data for students’ and the program’s performance evaluation. The most important source of information on students’ performance is the students’ portfolio. Students’ coursework is analyzed and graded by the professors using the eight Portfolio Aspects, which represent eight different areas in engineering education and should correspond to most of the program outcomes. Co-op employer surveys will provide the program evaluators with the students’ co-op performance.
Figure 3.5. The Generic Approach to the Assessment Process
Student exit surveys, alumni surveys, and co-op student surveys measure students’ satisfaction with the program. The questions in these surveys are designed to match the ABET outcomes (see Table 3.4 above).

Collecting evidence and summarizing the results from the surveys and students’ portfolios is handled by a database tabular structure. This very complex structure is then transformed into easy-to-read reports. The database reports accurately exhibit a program performance according to the inputs and also calculate the satisfactory level for ABET requirements. Each of the assessment inputs contributes to the final estimate of the program outcomes in certain percentages. The percentages presented in Figure 3.5 are subject to change in each assessment cycle.

*Database Entity Relationship Diagram*

The model foundations are built on the following assumption. First, the students’ portfolios will be collected only for the last three years of education (towards the college degree), assuming the nature of the ABET Engineering Criteria 2000 requirements. Also, the portfolio will be collected from only a sample of students for a given graduating class (cohort), due to the complexity and quantity of the material that has to be collected and processed mainly by the faculty of the program. Next, the co-op employer survey and the co-op student survey will include only students’ second, third, and fourth years of education; and the data will be collected from all the students from those graduating classes (cohorts), not just from those selected for the portfolio evaluation. Student exit surveys will include all senior students. Furthermore, the survey process of alumni will
include data given by two-year alumni and five-year alumni. Finally, the surveys’ data will be collected at the end of each summer quarter, which together with students’ coursework done in a given academic year makes one full assessment cycle. All input data will be numerical in range from 1 to 5, where 5 represents the maximum grade.

The following identified entities\(^\text{14}\) are an essential part of the database: student, employer, portfolio, alumni survey, student exit survey, employer survey, and co-op student survey. Each possesses certain properties, called attributes, which are used to include information that is required in the database. In agreement with the purpose of the database, all necessary information is collected into the appropriate attributes of the relevant entities. Entity Student is represented by the following attributes:

- SSN
- First Name
- Last Name
- Age
- Gender
- Address
- Year of Admission
- Year of Graduation

Entity Employer attributes are:

- Employer ID
- Employer Name
- Name of Contact Person
- Department
- Phone Number
- Fax Number
- Address

Entity Course attributes are:

- Course ID
- Professor

\(^{14}\) The purpose of a database is to store information about certain types of object, called entities.
- Department

Entity Portfolio has the eight portfolio aspects as its attributes.

Attributes of the Alumni Survey entity, Student Exit Survey entity, Employer Survey entity, and Co-op Student Survey entity are the actual survey questions. There are additional entities whose attributes do not affect the process: University, Professor, and Department. Because they do not affect the process, those attributes are not listed. The relationships among the entities and some of their attributes are shown in Figure 3.6.

Figure 3.6. Entity Relationship Diagram

Legend

<table>
<thead>
<tr>
<th>Entity</th>
<th>Attribute</th>
<th>Relationship</th>
</tr>
</thead>
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<tr>
<td>Student</td>
<td>Last Name</td>
<td>Address</td>
</tr>
<tr>
<td>Courses</td>
<td>Course ID</td>
<td></td>
</tr>
<tr>
<td>Employer</td>
<td>Employer ID</td>
<td></td>
</tr>
<tr>
<td>IME Department</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>Portfolio</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The central entity for the whole database system is Student. For convenience its attributes are divided into two groups; each is modeled as a separate entity. The first group carries the necessary attributes (SSN, First Name, Last Name, Year of Admission, Year of Graduation), and the second has optional attributes (Age, Address, Telephone Number). Optional attributes reveal additional information about an entity; they are not used as a handle (parameter) to the query. Entity Course is crucial for the assessment process because it is directly connected to IME program performance. Thus there is a strong one-to-one relationship between the students’ data and the assessment tools’ data. The logical primary key for this relationship is the student SSN.

**Design of the Relational Tables**

Most of the entities are directly modeled into relational tables; the attributes become the fields. The relationship among the tables is put together from the connection between the primary key (SSN) and the entities in Figure 3.6. The primary purpose of the database is to extract information gathered by the assessment tools for particular conditions. Database normalization is carried out based on first, second and third normal form rules\(^\text{15}\).

The employer table stores information about employers; each employer is assigned a specific ID. Different departments of one company have different IDs. Course details could be stored in the Portfolio table, but a separate table was made to honor the principles of relational database design.

\(^\text{15}\) First, second, and third normal form rules are a very important property of a relational database.
Different assessment tools are modeled as different tables because they are independent of each other in all respects. In other words, there is no direct relationship among them. So data is stored independently for each assessment tool. The information is then extracted by applying a particular filter to the tables. Processed information is about student performance, course performance, and, ultimately, program performance.

Tables accommodate all the data inputs. One table is designed for each different source of data. The relational model dictates that each row in a table be unique. However, all the data is linked to the students in some way so that the data administrator can get meaningful information on how well the program is carrying out ABET requirements today, and what should be changed in the future.

Valuable information can be drawn from statistics on the data taken directly from the tables — an example is an annual alumni survey. Data administrators can have a difficult time distilling information from the tables into well-organized, clear, and easy-to-read reports, because there is just too much information. Furthermore, it would be difficult to create a performance report on, for example, several generations of junior students. Therefore, in order to provide comprehensive views of the data collected, specific queries are created. A query can be thought of as a request of the database, the response to which is a new table, a report, or a form. There are several designed requests, including:
1. Student’s Coursework Evaluation Report for Eight Portfolio Aspects (Table 3.5)
2. Student’s Co-op Performance Report (Table 3.6)
3. Students’ Co-op Performance Report for Particular Year of Education (e.g., Juniors) for the Last Five Years (Table 3.7)
4. IME Program Outcomes Report on ABET Requirements by Alumni (Table 3.8)
5. IME Program Outcomes Final Report on ABET Requirements for Academic Year 2000 (Table 3.9)

Query Design

Figure 3.6, above, shows several implicit relationships among entity types. Moreover, whenever an attribute of one type refers to another entity type, some relationship exists [40]. For example, the attribute SSN refers to a student who attended the classes of the IME program, the attribute course number refers to a course that belongs to the IME program, and so on. In the entity relationship model, these references should not be represented as attributes but as relationships [40]. Later the attributes are converted into relationships between entity types. Figure 3.7 shows the entity relationship outline of the database for this model. In the figure, each entity is presented as a small window with its attributes listed below its name.

A join line between field lists tells Microsoft Access (the same is true for Oracle) how the data in one table are related to the data in the other. All this must be built in order to view, change, and analyze data in different ways. The data required for the analysis is formatted and grouped using queries. More important, queries are used as the source of records for forms, reports, and data access pages.
A group (set) of data connected by a common attribute is called a “grouping level.” Some fields in a relational table are critically important for the data analysis, and they are used as grouping levels for queries (e.g., year of student’s graduation). No redundant data is stored. Query parameters may be academic year, SSN, course number, year of admission, graduating class (cohort), year of graduation for alumni, etc. The SQL expressions of the queries can be found in Appendix A. For example, Query 3 (see Appendix A) is about selecting the data on students’ portfolio work for a particular graduating class (cohort) in particular academic year. Two input parameters taken by the query are student year (e.g., junior) and date year (e.g., 2001). The output of the

16 SQL is the standard language for interacting with a relational database.
query is a report on junior students’ portfolio evaluation in the 2001 academic year. This and other queries of the database provide initial information in a report form (see Appendix B) for the analysis phase of the assessment model.

**Analysis Phase**

In this phase the assessors use measures to find out why things are happening the way they are. They also want to find out which process is involved, what is wrong, and what and how big the opportunity for improvement is. The model answers these questions using the database design, a key building block for an organizational Six Sigma system [99].

The primary purpose of the database is to extract information gathered by assessment tools for particular conditions like process improvement. The relationship between students and assessment tools needs to be strong and one-to-one, so improvement areas are easy to identify. Parallel to this inference, the program outcomes measured using the same data are calculated as well (see Table 3.9).

A relational database has been used in this model. All the data is linked to the students in some way so that the data administrator will get more meaningful information on how well the program is doing, a program’s current requirements, and what should be changed in the future. Some valuable information can be drawn from statistics on the data taken directly from the tables. A two-year alumni annual survey serves as an example. (Two years after graduation provides feedback about strengths and
weaknesses of the program.) However, the information required for making certain quality improvement decisions is impossible to get by simply reading one of the tables. To analyze students' performance in the junior year across five years, several hundred data points need to be sorted out. The data administrator would have a difficult time retrieving information from the tables into well-organized, clear, and easy-to-read reports of students’ performance. These reports are presented in full in Chapter 4. Here are just a few IME program performance reports selected to illustrate the depth of the analysis as well as the clarity of the information delivered.

Table 3.5. Student's Coursework Evaluation Report for Eight Portfolio Aspects

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### Table 3.6. Student’s Co-op Performance Report

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<th>SSNo</th>
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<th>Employer</th>
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<th>Q3</th>
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<th>Q9</th>
<th>Q10</th>
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Summary for 'EmployerSurvey.SSNo' = 1111000 (3 detail records)

### Table 3.7. Juniors’ Co-op Performance Report for the Last Five Years

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<td>4.5</td>
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Summary for 'DateYear' = 1994 (13 detail records)

Summary for 'DateYear' = 1995 (13 detail records)

Summary for 'DateYear' = 1996 (12 detail records)

Summary for 'DateYear' = 1997 (13 detail records)

Summary for 'DateYear' = 1998 (13 detail records)

Summary for 'DateYear' = 1999 (13 detail records)

Summary for 'DateYear' = 2000 (13 detail records)

Summary for 'DateYear' = 2001 (13 detail records)
Table 3.8. IME Program Outcome Report on ABET Requirements by Alumni

Report 5. Evaluation of IME Program Outcomes by Alumni – Class of ’95

<table>
<thead>
<tr>
<th>Alumni from year:</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program outcome (a):</td>
<td>4.50</td>
</tr>
<tr>
<td>outcome (b):</td>
<td>4.10</td>
</tr>
<tr>
<td>outcome (c):</td>
<td>4.10</td>
</tr>
<tr>
<td>outcome (d):</td>
<td>2.20</td>
</tr>
<tr>
<td>outcome (e):</td>
<td>3.40</td>
</tr>
<tr>
<td>outcome (f):</td>
<td>4.15</td>
</tr>
<tr>
<td>outcome (g):</td>
<td>4.20</td>
</tr>
<tr>
<td>outcome (h):</td>
<td>3.60</td>
</tr>
<tr>
<td>outcome (i):</td>
<td>4.40</td>
</tr>
<tr>
<td>outcome (j):</td>
<td>3.90</td>
</tr>
<tr>
<td>outcome (k):</td>
<td>3.30</td>
</tr>
</tbody>
</table>

Table 3.9. IME Program Outcomes’ Evaluation Final Report on ABET Requirements for Academic Year 2000


<table>
<thead>
<tr>
<th>Program outcome (a):</th>
<th>3.60</th>
</tr>
</thead>
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<tr>
<td>outcome (b):</td>
<td>3.74</td>
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<tr>
<td>outcome (c):</td>
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<tr>
<td>outcome (d):</td>
<td>3.61</td>
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<tr>
<td>outcome (e):</td>
<td>3.92</td>
</tr>
<tr>
<td>outcome (f):</td>
<td>3.71</td>
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<tr>
<td>outcome (g):</td>
<td>3.45</td>
</tr>
<tr>
<td>outcome (h):</td>
<td>3.86</td>
</tr>
<tr>
<td>outcome (i):</td>
<td>3.71</td>
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<tr>
<td>outcome (j):</td>
<td>3.72</td>
</tr>
<tr>
<td>outcome (k):</td>
<td>3.83</td>
</tr>
</tbody>
</table>
Report 5, presented in Table 3.8, is one of the four final assessment reports extracted from the database for the program performance evaluation. Report 5 represents alumni evaluations for a particular academic year. The report is a simple list of the program outcomes’ values. The other three reports are obtained from other sources (assessment tools): students’ coursework (portfolio), students’ co-op program, and senior students’ interviews. In Figure 3.8 the broken line in the map of the generic assessment process graphically represents Report 5.

Figure 3.8. The Alumni Evaluation as 10% of the Final Value on a Program Outcomes Evaluation
Each report makes a contribution to the final value of the program outcomes evaluation by a certain percentage (see Figure 3.5). The final report of the program outcomes evaluation, Table 3.9, is the answer to how well the engineering program is doing according to the students’ work and the external customers’ needs. It is designed to directly answer ABET Engineering Criteria 2000. This simplified summary is, however, the result of a large, complex, and diverse data collection. As many as 64,000 data points are processed, summarized, and translated into dozens of reports for further analysis each year. Program outcomes in the final report are calculated as follows:

\[
\text{Outcome (a)} = \text{Alumni Report (a=4.5)} \times 0.10 + \text{Student Exit Report (a=4)} \times 0.10 + \text{Portfolio Report (a=2.2)} \times 0.55 + \text{Co-op Report (a=3.75)} \times 0.25 = 3.00 \\
\text{Outcome (b)} = \text{Alumni Report (b outcome)} \times 0.10 + \text{Student Exit Report (b outcome)} \times 0.10 + \text{Portfolio Report (b outcome)} \times 0.55 + \text{Co-op Report (b outcome)} \times 0.25 = 3.74 \\
\text{Outcome (c)} = \ldots
\]

In other words, alumni assessment of program outcome (a) influences the final value of program outcome (a) by 10%. Student exit assessment relevant to the outcome (a) influences the final value of program outcome (a) by 10%. The final value of program outcome (b) and the rest of the outcomes are calculated the same way. The percentages used in equations (1) and (2), the formulas for calculating the final value for program outcomes (a) and (b), are subject to change according to assessment committee decisions.
**Statistical Inference Analysis**

The analysis phase of the model is vital for successful implementation of the necessary improvements in the system. It starts with analyzing data from the reports (See Tables 3.5, 3.6, and 3.7). The assessment team first checks whether the value of each of the 11 program outcomes (see Report 6 in Table 3.9) falls within the program’s (or its customers’) specification limits. Let us assume that the value of program outcome (d) is below the lower specification limit and the process is out of control. The assessors then check each set of program outcomes from the four evaluation reports: Alumni Report, Employers’ Report, Professors, (Portfolio) Report, and Senior Students, Reports (Students’ Exit Interviews) for program outcome (d). Note that the specification limits are exclusively developed for each of these (a) through (k) outcomes. One or more reports (e.g., the alumni report and the employer survey) may show that program outcome (d) is below the required quality level. The review of the results has exposed students’ inability to function in multidisciplinary teams — outcome (d) of the program. The structure of the program curriculum was not sensitive enough to detect this problem, but students’ performance in the co-op program did: The students did not live up to their employers’ expectations regarding their ability to function in multidisciplinary teams. In the survey designed for co-op employers, questions 9 and 12 addressed this issue. The value of program outcome (d) of the employers’ report is the result of data gathered from questions 9 and 12 of the employer survey. Figure 3.9 represents the employers’ evaluations of students’ ability to be efficient in multidisciplinary teams. It shows relatively low performance for three straight years.
This is alarming information. However, it is not clear yet what should be done differently so that students grasp, communicate, and grow within a multidisciplinary environment. At this point it is very hard to identify the problem within the bounds of the existing curriculum of the IME program.

To narrow down the problem, other relevant reports were analyzed. Engineering science, the element of the curriculum relevant to the students' understanding of the multidisciplinary setting, is monitored using portfolio aspect VIII as an assessment tool. Figure 3.10 shows junior students' performance in the area of engineering science.

Several of the courses reveal a slowdown in progress over the past three years. Courses INDS440 and INDS452 are the only ones that show progress in the last year. It also appears that INDS411 and INDS454 have exhibited the lowest overall score performance.
Figure 3.10. Portfolio Aspect VIII Review — Juniors’ Abilities in Engineering Science

Students’ coursework, now in the form of rich portfolio data, enables the assessors to isolate the problem more closely. Portfolio analysis of students’ performance in the area of information technology is relevant (see Figure 3.11). Most of the courses recorded setback in progress over the past three years. Course INDS411 has the lowest performance level of all. In practice, this means that students use design software very successfully, but they demonstrate poor performance in using statistical and quality control software tools.

The end result of the analysis indicates that improvements should be made in the areas of quality control, operations research, and engineering economy. A closer look at these areas of study will help the program and the college assessors to determine the
Detecting the root of the problem would be difficult without the database system that provides us with detailed information on each input (assessment surveys and portfolios). As shown in Figure 3.10, it is possible to compare several years of students’ co-op performance and get a direct insight into continuous improvement in a given area.
of education. This depends heavily on statistical quality control tools such as design of experiments (DOE) and analysis of variance (ANOVA). The information gathered by DOE or ANOVA can help identify the settings of key variables for process optimization and change opportunities. Using these and similar statistical techniques — tools of Six Sigma — provides assessors with enough information to approach the next phase in the model.

Still, in educational settings statistics cannot be overemphasized, particularly in the early stage of the analytical process. Moreover, it can ease the process if the organization spends considerable time and money collecting and analyzing data [15].

**Design and Implementation Phase — Implementing Improvements**

After the collected data is analyzed and conclusions are reached, improvements must be implemented so that the overall process is enhanced. In the implementation phase, faculty, together with other assessment team members, will identify and apply solutions for putting into practice learning outcomes. This is also the focus of Six Sigma initiatives for customer satisfaction, improvement of the cycle times, improvement of the defect rates, and so on [24].

To avoid possible drawbacks of the process improvement (such as lack of creativity, failure to think through solutions carefully, and organizational resistance), the following questions about possible solutions proposed by P.S. Pande et al. [99] may help:
- What possible actions or ideas will help us address the root cause of the problem and achieve our goal?
- Which of these ideas form workable potential solutions?
- Which solution will most likely achieve our goal with the least cost and disruption?
- How do we test our chosen solution and then implement it permanently?

Six Sigma methodology usually utilizes a combination of ideas that together make up a plan for results, whether it is a changed course outline or curriculum content, implementation of new teaching techniques, or enhanced service delivery to the students and external customers. Less frequently there is a need to reconstruct a program’s curriculum, especially if the same problem is detected within different courses.

Changing or fixing a process demands strong project management skills. To paraphrase Mark Twain, “I’m all for progress, it’s change I hate.” Six Sigma philosophy requires that the change always be initiated from above. However, the faculty must play a major role in program improvement. Also, the management team of experienced educators should be supported by industry employers, since the problem is directly related to the students’ performance at co-op. In other words, all interested parties must be involved in initiating the changes, developing the right solutions, and implementing the necessary transformations.
Control Phase

After the implementation phase, the process should have been improved. At this stage it is essential to institute steps that guarantee stability in the system — that is, the process must be controlled and stabilized so it can stay at the newly improved level until the next cycle begins. The final goal of an engineering program is to achieve its program objectives and program outcomes. In the control phase the emphasis is on the activities that help to control the educational system in place, as well as techniques to further develop and qualify potential solutions. Appropriate statistical process control (SPC) tools need to be used as screening techniques. The faculty and college administrators must implement measures that will control the key variables within the operating limits. In some other instances it could be a matter of simply managing the processes at the higher administrative level. Control of the process is one way of controlling the key variables of the outcomes that an engineering program wishes to achieve.

Control of the Process

In the course of measuring and analyzing an assessment process, it’s often possible to draw valid conclusions simply by looking at the data. The fact is, however, that in many instances, these so-called “patterns” are simply random variations [14]. In order to detect patterns or to test the quality of data, program evaluators use techniques such as analysis of variance, the test of significance for continuous data that can be used to compare equal groups of data.
In Six Sigma, ANOVA has different applications. Using one-way ANOVA it is possible to determine, for example, whether there is a sufficient amount of evidence to indicate that population means differ with respect to knowledge that students are required to demonstrate regarding the program objectives. To illustrate the one-way ANOVA application, an example is used to determine whether juniors of academic year 2000 exhibit inconsistency in performance in the area of engineering science (portfolio aspect VIII data collection). Through the example it is possible to:

- Confirm a problem or a meaningful change in performance
- Check the validity of the data
- Develop a root-cause hypothesis based on patterns and differences.

Figure 3.10 provides information on junior students’ abilities in engineering science by screening four consecutive years. However, it shows only that there is significant difference in students’ performance in this area of education for each course and each year analyzed. Analyzing only one academic year, it will be possible to determine whether there are any significant differences among the seven courses with respect to engineering science, which is one of the program outcome requirements.

A sample of ten students is graded in each of seven courses required for junior students for academic year 2000. Professors grade the students’ performances, defined by portfolio aspect VIII, that determine juniors’ knowledge in the area of engineering science.
Table 3.10. Junior Students’ Performance in the Area of Engineering Science in Academic Year 2000

<table>
<thead>
<tr>
<th>STUDENT</th>
<th>Course</th>
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<td></td>
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<td>475 Manufact. Control</td>
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<td>411 Quality Control</td>
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<td>452 Facilities Design</td>
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<td></td>
<td>475 Manufact. Control</td>
<td></td>
<td>411 Quality Control</td>
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<td>452 Facilities Design</td>
<td></td>
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<td>4.00</td>
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<td>3.75</td>
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\[
\bar{X}_1 = 3.98 \quad \bar{X}_2 = 4.43 \quad \bar{X}_3 = 3.75 \quad \bar{X}_4 = 3.28 \quad \bar{X}_5 = 4.48 \quad \bar{X}_6 = 3.45 \quad \bar{X}_7 = 3.68
\]

Under the assumptions that the \( c \) groups (\( c \) = number of groups being compared) of the factor being studied represent populations whose outcome measurements are randomly and independently drawn, follow a normal distribution, and have equal variances, the null hypothesis of no difference in the population means

\[
H_0: \mu_1 = \mu_2 = \ldots = \mu_c
\]

may be tested against the alternative that not all the \( c \) population means are equal.

\[
H_1: \text{Not all } \mu_j \text{ are equal} \quad \text{(where } j = 1, 2, \ldots, c \text{),}
\]

Table 3.10 and Figure 3.12 are visual displays of the data; it is possible to see how the measurements distribute around their own group (course) means as well as around the overall group mean \( \bar{X} \).
The box plot provides a sense of how each group mean compares to the overall mean. It is obvious from Table 3.10 and Figure 3.12 that there are differences in the sample means for the seven courses. This raises the question of whether these sample results differ significantly, in which case the assessment committee would conclude that the population averages are not all equal.

The null hypothesis states that there is no difference among the groups (courses) in the average grade for students’ knowledge in engineering science.

\[ H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 \]
On the other hand, the alternative hypothesis states that at least one of the courses differs with respect to the average grade required to complete this program outcome requirement.

\[ H_1: \text{Not all the means are equal} \]

To construct the ANOVA Summary Table 3.11 it is necessary to compute the sample means in each group (Table 3.10) and the overall mean.

The overall mean \( \overline{X} = \frac{\sum_{j=1}^{c} \sum_{i=1}^{n_j} X_{ij}}{n} \), where

- \( X_{ij} = \text{ij}^{th} \) observation in group \( j \) (student’s grade in \( j \) course)
- \( \overline{X}_j = \text{sample mean of group } j \)
- \( c = \text{number of courses being compared} \)
- \( n_j = \text{number of students taking a particular (j) course} \)
- \( n = \text{total number of observations in all courses combined} \)

So \( \frac{\sum_{j=1}^{c} \sum_{i=1}^{n_j} X_{ij}}{n} = \frac{3.5 + 4 + \ldots + 4.25 + \ldots + 3.75}{70} = 4.34. \)

To perform an ANOVA test of equality of population means the total variation, Sum of Squares Total (SST), is subdivided into two parts, variation among the groups (SSA) and variation within the groups (SSW).

Among groups variation (SSA) = \( \sum_{j=1}^{c} n_j (\overline{X}_j - \overline{X})^2 = \)

\[ = (10)(3.98 - 4.34)^2 + (10)(4.43 - 4.34)^2 + (10)(3.75 - 4.34)^2 + \ldots + (10)(3.68 - 4.34)^2 = 12.68 \]
Within group variation (SSW) = $\sum_{j=1}^{c} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2 =$

$= (3.50 - 3.98)^2 + (4.00 - 3.98)^2 + (3.50 - 3.98)^2 + \ldots + (4.50 - 4.43)^2 + (4.25 - 4.43)^2 +$

$+ (4.00 - 4.43)^2 + \ldots + (4.00 - 3.75)^2 + (4.00 - 3.75)^2 + (4.00 - 3.75)^2 + \ldots +$

$+ (3.25 - 3.28)^2 + (3.00 - 3.28)^2 + (3.50 - 3.28)^2 + \ldots + (4.50 - 4.48)^2 +$

$+ (4.75 - 4.48)^2 + (4.50 - 4.48)^2 + \ldots + (3.00 - 3.45)^2 + (3.25 - 3.45)^2 + (3.25 - 3.45)^2 + \ldots +$

$+ (3.78 - 3.68)^2 + (3.50 - 3.68)^2 + (3.50 - 3.68)^2 + \ldots + (3.75 - 3.68)^2 = 6.66$

Total variation (SST) = $\sum_{j=1}^{c} \sum_{i=1}^{n_j} (X_{ij} - \bar{X})^2 =$

$= (3.50 - 4.34)^2 + (4.00 - 4.34)^2 + (3.50 - 4.34)^2 + (3.50 - 4.34)^2 + (4.25 - 4.34)^2 +$

$+ (4.00 - 4.34)^2 + \ldots + (3.50 - 4.34)^2 + (4.00 - 4.34)^2 + (3.75 - 4.34)^2 = 19.33$

Since $c$ courses are being compared, there are $c - 1$ degrees of freedom associated

with the Sum of Squares Among groups (SSA). Also, each of the $c$ courses contributes

$n_j - 1$ degrees of freedom and $\sum_{j=1}^{c} (n_j - 1) = n - c$. There is $n - c$ degrees of freedom

associated with the Sum of Squares Within groups (SSW).

Dividing each of the sums of squares with its associated degrees of freedom it is

possible to obtain three variances, better known as mean squares: MSA, MSW, and

MST. In this example $c = 7$ and $n = 70$; therefore

$$MSA = s^2 = \frac{SSA}{c-1} = \frac{12.67}{6} = 2.11 \quad \text{MSW} = s^2 = \frac{SSW}{n-c} = \frac{6.6}{63} = 0.11$$

Since a variance is computed by dividing the sum of squared differences with

associated degrees of freedom, the above expressions of mean squares are all
variances. If the null hypothesis is true and there are no real differences in the c group means, $S_A^2$ and $S_W^2$ provide an estimate for the variance $\sigma^2$ integral in the data. The ratio of the variances is provided by F test, which is equal to the ratio of the Mean Square Among groups (MSA) and Mean Square Within groups (MSW).

$$F = \frac{MSA}{MSW} \quad \text{or} \quad F = \frac{s_A^2}{s_W^2} = \frac{2.11}{0.11} = 19.99$$

F test follows an F distribution with $c - 1$ and $n - c$ degrees of freedom. For $\alpha = 0.05$ level of significance upper tailed critical value is $F_{U(6,63)} = 2.25$ (F distribution) and is exceeded by F-test. This leads to only one conclusion: Reject $H_0$. Regions of rejection and nonrejection when using ANOVA to test $H_0$ are shown in Figure 3.13.

![Figure 3.13. Regions of Rejection and Nonrejection When Using ANOVA to test $H_0$](image-url)

The probability of obtaining an F statistic, p-value, of approximately 20 or larger (Table 3.11), given that the null hypothesis is true, is equal to 0.0000. Since this p-value is less than $\alpha = 0.05$, the null hypothesis is rejected.
Table 3.11. Analysis of Variance Table for the Assessment Study

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F critc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>12.67</td>
<td>6</td>
<td>2.11</td>
<td>19.99</td>
<td>6.3E-13</td>
<td>2.25</td>
</tr>
<tr>
<td>Within Groups</td>
<td>6.66</td>
<td>63</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19.33</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rejection of H₀ indicates that among-group variation is larger than the population variability. Even if there is no real effect of being in different groups (e.g., the null hypothesis is true), there will likely be differences among group means. This is because variability among students will make the sample means different just because the samples are different.

Using a one-way ANOVA test, a sufficient amount of evidence has been found to conclude that population means differ with respect to knowledge that students are required to demonstrate regarding their program objectives. What is not known, however, is which course or courses differ from the other(s). To determine exactly which course or courses differ, the Tukey-Kramer Procedure may be used. This procedure enables the evaluators to simultaneously examine comparisons among all groups.

Nevertheless, before this technique is used it is imperative to determine whether or not a comparison of all the courses will be useful to the evaluators. This depends primarily on the nature of the courses compared. In this example, the focus was on students’ knowledge in engineering science, which is a very broad area. These courses may be created to approach the problem very differently. More specific requirements must be
set up for any further statistical analysis. Otherwise, the conclusions will not be valuable. In addition, more than 50% of data collected were initially categorical types, which is one more reason to include other than statistical techniques in making certain decisions.

If, on the other hand, the evaluators want to know if there is a significant difference among course means when assessing students’ mathematical skills, the problem is a lot clearer. Finding that there is a significant difference in students’ performance in math is very alarming. In this case the program evaluators need to know exactly which course’s mean is significantly different from the overall population mean. In other words, it is very important to identify the courses in which the students received grades that are significantly higher or lower than expected.
Two-Loop Model

The process described here provides answers for program outcomes, but the same process is applied to program objectives. ABET requires from each engineering program seeking accreditation that its executives map the program objectives to the program outcomes in order to prove that their graduates are, in fact, receiving a quality education. In the case of the IME Program, each educational objective meets several program outcomes (Table 3.1). Figure 3.14 shows the assessment process in two parallel loops. Only with this element is this generic assessment model complete and its objective to generate continuous improvement achieved.

Figure 3.14. Assessment Process in Two Parallel Loops
The generic assessment model described here is a comprehensive assessment composition that penetrates into an educational system of higher education as deep as the evaluation of every project of every course in the program. It builds a systematic assessment of the program using Six Sigma methodology, which in the end will add value to the college as a whole.
Chapter 4. Results

4.1. Analysis

The Six Sigma breakthrough strategy provides a way to statistically view IME program outcomes requirements and then quantitatively evaluate how those requirements are being met [58]. Two types of tools are used to identify the most likely causes of “defects”: data analysis tools and process analysis tools. This time both types of tools are used simultaneously. Also, to get reliable results it was important to analyze a significant amount of data. The first information in the analysis is the final report on the overall performance of all 11 IME program outcomes (see Figure 4.1).

**IME Program Outcomes Final Report**

<table>
<thead>
<tr>
<th>IME Program Outcomes for Academic Year: 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>IME outcome (a): 2.96</td>
</tr>
<tr>
<td>IME outcome (b): 2.79</td>
</tr>
<tr>
<td>IME outcome (c): 3.80</td>
</tr>
<tr>
<td>IME outcome (d): 3.37</td>
</tr>
<tr>
<td>IME outcome (e): 4.01</td>
</tr>
<tr>
<td>IME outcome (f): 4.41</td>
</tr>
<tr>
<td>IME outcome (g): 3.48</td>
</tr>
<tr>
<td>IME outcome (h): 3.62</td>
</tr>
<tr>
<td>IME outcome (i): 3.64</td>
</tr>
<tr>
<td>IME outcome (j): 3.39</td>
</tr>
<tr>
<td>IME outcome (k): 3.41</td>
</tr>
</tbody>
</table>

Figure 4.1. The Final Report of the Assessment Evaluation for Year 2001
On the surface it looks as if the program is doing well. This evaluation is the result of four other assessment tools: the IME Alumni Survey, the IME Student Exit Survey, the IME Co-op Employer Survey, and the IME Students’ Portfolio (see reports 8, 9, 10, and 11 in Appendix B). Figure 4.2 compares the 11 IME program outcomes evaluated by each assessment tool to the final value of the assessment.

![Figure 4.2. The IME Program Outcomes Final Evaluation Against Four Assessment Tools](image)

Figure 4.2 shows that several program outcomes ((c), (g), (h), (j), and (k)) remain concentrated around value 3.5 with little variation. Outcomes ((a), (b), (d), (e), and (f)),
however, exhibit a larger spread in data. Table 4.1 illustrates a relative measure of variation for all the outcomes.

Figure 4.3. The IME Program Outcomes Final Evaluation for the Last Five Academic Years

As a relative measure the coefficient of variation is particularly useful when comparing the variability of two or more sets of data that are expressed in different units or measurement. The 11 program outcomes are expressed in the same units, but the initial data collection was focused on the measurement of very different skills. Table 4.1
shows that the program evaluation for outcomes (a), (b), (d), and (e) is much more variable in the last five years than program evaluation for outcomes (c), (f), (g), (h), (i), (j), and (k) relative to the mean. For IME program outcome (a), the coefficient of variation is $\text{CV}_a = 17.51\%$; for program outcome (b), the coefficient of variation is $\text{CV}_b = 20.43\%$; program outcome (d), the coefficient of variation is $\text{CV}_d = 15.38\%$; for program outcome (e), the coefficient of variation is $\text{CV}_e = 15.71\%$.

Table 4.1. Coefficient of Variation for the 11 IME Program Outcomes

<table>
<thead>
<tr>
<th></th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>3.00</td>
<td>2.96</td>
<td>2.03</td>
<td>2.26</td>
<td>2.96</td>
<td>17.51%</td>
</tr>
<tr>
<td>b</td>
<td>3.79</td>
<td>3.35</td>
<td>2.29</td>
<td>3.79</td>
<td>2.79</td>
<td>20.43%</td>
</tr>
<tr>
<td>c</td>
<td>3.80</td>
<td>3.25</td>
<td>3.95</td>
<td>3.92</td>
<td>3.80</td>
<td>7.60%</td>
</tr>
<tr>
<td>d</td>
<td>2.50</td>
<td>2.58</td>
<td>3.54</td>
<td>3.06</td>
<td>3.37</td>
<td>15.38%</td>
</tr>
<tr>
<td>e</td>
<td>4.01</td>
<td>4.80</td>
<td>4.12</td>
<td>3.04</td>
<td>4.01</td>
<td>15.71%</td>
</tr>
<tr>
<td>f</td>
<td>4.50</td>
<td>4.00</td>
<td>4.70</td>
<td>3.90</td>
<td>4.41</td>
<td>7.90%</td>
</tr>
<tr>
<td>g</td>
<td>3.48</td>
<td>3.48</td>
<td>3.48</td>
<td>3.21</td>
<td>3.48</td>
<td>3.48%</td>
</tr>
<tr>
<td>h</td>
<td>3.62</td>
<td>3.62</td>
<td>3.62</td>
<td>3.00</td>
<td>3.62</td>
<td>7.97%</td>
</tr>
<tr>
<td>i</td>
<td>3.64</td>
<td>3.64</td>
<td>3.64</td>
<td>3.26</td>
<td>3.64</td>
<td>4.73%</td>
</tr>
<tr>
<td>j</td>
<td>3.18</td>
<td>3.51</td>
<td>3.41</td>
<td>3.10</td>
<td>3.39</td>
<td>5.17%</td>
</tr>
<tr>
<td>k</td>
<td>3.11</td>
<td>3.21</td>
<td>3.22</td>
<td>3.19</td>
<td>3.41</td>
<td>3.40%</td>
</tr>
</tbody>
</table>

According to the initial analysis, search for improvement lies in IME program outcomes (a) and (b). Figure 4.1 indicates that outcome (k) might be subject to improvement as well. On the other hand, Table 4.1 uncovers a wide spread of data points related to outcomes (d) and (e). But first, two things must be examined: students’ ability to apply knowledge of mathematics, science, and engineering (program outcome (a)), and their ability to design and conduct experiments, as well as to analyze and interpret data (program outcome (b)).
As the most influential tool in the entire assessment process, the portfolio serves as a forum for assessing student learning and guiding intellectual development. For the institutional (or program) portfolio, the documented professional achievement is the students’ experience in design within an engineering major. The portfolio presents a student’s best work rather than a collection of all work or a range of performance. Therefore, it is the first place to look for the answers.

Table 3.4 shows that outcome (a) is directly connected to portfolio aspect I and portfolio aspect VIII. Meanwhile, portfolio aspect V is directly linked to outcome (b). Figure 4.4 shows how the portfolios of senior students in 2001 reflect their performance in the areas of math, science, and data analysis. Thanks to the model design, it is possible to generate such a report directly from the database.

There were 13 IME senior students during academic year 2001, all taking a sequence of required courses. Their performance was very good with the exception of INDS512, Applied Regression Analysis. It is also noticeable that the evaluation of students’ skills in calculus, portfolio aspect I, was somewhat lower than the evaluation of other portfolio aspects. Still, these results show that the seniors of 2001 performed very well.

Does that mean the IME program is doing well, and that there is no reason to make any drastic changes? Of course not! There is a lot more to investigate about the senior generation. It is important to look at all other relevant data collected through other
assessment tools. But even before that, Table 4.2 compares 2001 seniors with a few previous cohorts of seniors.

**Table 4.2. Senior Students' Ability to Apply Mathematics Knowledge**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IND512</td>
<td>2.29</td>
<td>2.91</td>
<td>2.69</td>
<td>2.01</td>
<td>2.14</td>
</tr>
<tr>
<td>IND520</td>
<td>3.15</td>
<td>3.26</td>
<td>3.13</td>
<td>3.25</td>
<td>3.84</td>
</tr>
<tr>
<td>IND555</td>
<td>3.00</td>
<td>3.99</td>
<td>2.92</td>
<td>3.46</td>
<td>4.14</td>
</tr>
<tr>
<td>IND556</td>
<td>2.87</td>
<td>2.99</td>
<td>3.84</td>
<td>3.84</td>
<td>3.61</td>
</tr>
<tr>
<td>MINE585</td>
<td>4.07</td>
<td>3.76</td>
<td>4.15</td>
<td>4.57</td>
<td>4.38</td>
</tr>
<tr>
<td>MINE586</td>
<td>4.00</td>
<td>4.15</td>
<td>3.84</td>
<td>4.50</td>
<td>4.53</td>
</tr>
<tr>
<td>MINE587</td>
<td>3.25</td>
<td>3.57</td>
<td>4.00</td>
<td>4.00</td>
<td>4.30</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>3.23</strong></td>
<td><strong>3.52</strong></td>
<td><strong>3.51</strong></td>
<td><strong>3.66</strong></td>
<td><strong>3.85</strong></td>
</tr>
</tbody>
</table>
It is possible to present the same information more clearly using a diagram. Figure 4.5 presents information on five cohorts of senior students and their ability to apply knowledge in mathematics.

![Figure 4.5. Senior Students' Performance in the Area of Mathematics](image)

There are two important conclusions to draw from this figure. First is that over the five-year period, seniors’ performance in applied mathematics has exhibited a negative trend. The second is that students’ performance in INDS512, Applied Regression Analysis, has been significantly lower than in other senior courses, a fact that requires more detailed analysis.
Figure 4.6 reveals that students’ performance in Applied Regression Analysis, with the focus on their ability to apply mathematics, has been a problem through several cohorts.

![Figure 4.6. Students’ Performance in Applied Regression Analysis Course](image1)

Seniors have excellent scores for their ability to use computers and understand information systems, except for the course in Regression Analysis (see Figure 4.7). This particular course has the lowest GPA of all educational skills that were measured by portfolio aspects.

![Figure 4.7. Ability of 2001 Senior Students to Master Information Systems](image2)
This could have several causes: The software used in this particular course might not be easy to master. The instructor’s expectations might be higher than those of his colleagues. But the most likely is that students weren’t prepared for this course. Table 4.3 presents information on students’ performance in INDS512 for the last five years; this is extracted from Report 4 in Appendix B. Certainly, more detailed analysis is necessary. To clarify this problem it would be very important to involve the students’ opinions as well.

Table 4.3. Senior Students’ Performance in the Applied Regression Analysis Course for the Last Five Years

<table>
<thead>
<tr>
<th>Year</th>
<th>PA1</th>
<th>PA2</th>
<th>PA3</th>
<th>PA4</th>
<th>PA5</th>
<th>PA6</th>
<th>PA7</th>
<th>PA8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2.29</td>
<td>2.91</td>
<td>2.69</td>
<td>2.67</td>
<td></td>
<td></td>
<td></td>
<td>2.76</td>
</tr>
<tr>
<td>2000</td>
<td>3.00</td>
<td>3.25</td>
<td>2.99</td>
<td>3.45</td>
<td></td>
<td></td>
<td></td>
<td>3.49</td>
</tr>
<tr>
<td>1999</td>
<td>3.15</td>
<td>3.85</td>
<td>2.69</td>
<td>3.12</td>
<td></td>
<td></td>
<td></td>
<td>3.43</td>
</tr>
<tr>
<td>1998</td>
<td>2.75</td>
<td>3.92</td>
<td>3.87</td>
<td>2.87</td>
<td></td>
<td></td>
<td></td>
<td>3.12</td>
</tr>
<tr>
<td>1997</td>
<td>2.54</td>
<td>2.54</td>
<td>3.50</td>
<td>3.87</td>
<td></td>
<td></td>
<td></td>
<td>3.20</td>
</tr>
</tbody>
</table>

It seems that the 2001 senior students have the lowest overall scores in this course. The instructor was evaluating students’ final projects as well as the final exam. He was grading students’ math and science skills, writing skills, engineering design skills, and skills in information technology.

If the IME curriculum was not designed to provide students with sufficient prerequisite knowledge for the course in regression analysis, the evidence should exist in the coursework of pre-junior and junior students in the area of science, particularly mathematics. Tables 4.4 and 4.5 show portfolio evaluation for third- and fourth-year students.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>PA1</th>
<th>PA2</th>
<th>PA3</th>
<th>PA4</th>
<th>PA5</th>
<th>PA6</th>
<th>PA7</th>
<th>PA8</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDS411</td>
<td>3.2</td>
<td>3.2</td>
<td>3.4</td>
<td>3.4</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDS438</td>
<td>3.8</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDS440</td>
<td>3.1</td>
<td>4.2</td>
<td>4.2</td>
<td>4.5</td>
<td>4.0</td>
<td>3.6</td>
<td>3.6</td>
<td>4.4</td>
</tr>
<tr>
<td>INDS452</td>
<td>3.6</td>
<td>4.2</td>
<td>4.2</td>
<td>3.8</td>
<td>4.0</td>
<td>3.6</td>
<td>3.6</td>
<td>4.4</td>
</tr>
<tr>
<td>INDS453</td>
<td>3.2</td>
<td>3.4</td>
<td></td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td>3.6</td>
</tr>
<tr>
<td>INDS454</td>
<td>3.0</td>
<td>4.2</td>
<td>3.8</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>INDS470</td>
<td>3.6</td>
<td>3.8</td>
<td></td>
<td></td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDS475</td>
<td>3.8</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
<td></td>
<td></td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.3</td>
<td>3.9</td>
<td>3.9</td>
<td>3.8</td>
<td>3.9</td>
<td>3.5</td>
<td>3.4</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Table 4.5. Pre-juniors' Course Performance in Academic Year 1999

<table>
<thead>
<tr>
<th>Course Code</th>
<th>PA1</th>
<th>PA2</th>
<th>PA3</th>
<th>PA4</th>
<th>PA5</th>
<th>PA6</th>
<th>PA7</th>
<th>PA8</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENFD371</td>
<td>3.7</td>
<td>3.7</td>
<td>3.9</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>ENFD383</td>
<td>3.2</td>
<td>3.9</td>
<td>3.9</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td>ENFD385</td>
<td>3.1</td>
<td>3.6</td>
<td>3.7</td>
<td>3.7</td>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>INDS322</td>
<td>2.5</td>
<td>3.7</td>
<td>3.8</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td>2.9</td>
</tr>
<tr>
<td>INDS341</td>
<td>2.1</td>
<td></td>
<td>3.0</td>
<td>3.0</td>
<td>2.8</td>
<td>2.8</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>INDS354</td>
<td>3.6</td>
<td>4.1</td>
<td>3.8</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
<td>3.8</td>
</tr>
<tr>
<td>INDS355</td>
<td>3.0</td>
<td>4.0</td>
<td>3.6</td>
<td>3.3</td>
<td>3.8</td>
<td>3.7</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>MINE340</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>2.9</td>
<td>4.0</td>
<td>3.8</td>
<td>3.8</td>
<td>3.7</td>
<td>3.7</td>
<td>3.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Evaluated during their pre-junior, junior and senior years, the same cluster of students did the poorest job during the pre-junior year (see Figure 4.8). Moreover, the students’ performance in courses that require quantitative analysis and math is the most problematic in their pre-junior year. This information is extracted from Report 3 in the database (see Appendix B).

Further analysis of students’ performance by other instruments of assessment reveals more problems. Students’ co-op performance assessment has shown that students’ ability to communicate effectively (program outcome (g)), as well as their ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (program outcome (k)) did not meet the expectations of their employers (see Figure 4.2).
After analysis of IME program outcomes for overall co-op students’ performance, it was important to review employer evaluations for all three generations that do co-op (sophomore, pre-junior, junior) in year 2001. Figure 4.9 (Report 7 from the database; see Appendix B) gives the outline of the employer assessment.

Table 3.4 correlates all five assessment tools mapped to IME program outcomes, mapping each IME program outcome to specific question(s) in the co-op employer’s survey. From this table it is clear that the critical program outcome, (g), is represented in the employer survey by question 2, and program outcome (k) is represented in the employer survey by questions 7, 10, and 14. Figures 4.10 and 4.11 depict the results of the employer survey.

![Table 3.4](image)

Figure 4.9. Employer Evaluation for All Three Generations for Year 2001
Student Writes Clearly and Concisely, Speaks Effectively and Clearly

Figure 4.10. Employer Evaluation of Student Communication Skills

Student Applies Classroom Learning to Work Situation

Figure 4.11. Employer Evaluation of Student Ability to Apply Classroom Learning to Work Situations – for Year 2001
Employers judged sophomores’ communication skills to be the poorest. This problem does improve over time; still, even juniors do not receive impressive results in communicating effectively in the workplace: Their average result is only 2.78. In the classroom, however, juniors performed much better. Portfolio aspect II (Writing and Communication Skills) has shown an excellent grade average of 3.89. It is important to further investigate this very different assessment result for the same skill. The best way to do this is to introduce a student focus group as an additional assessment tool. At this point the problem is isolated, and a focus group will be able to analyze it and provide the assessors with potential solutions.

The problem articulated in Figure 4.11 is also very disturbing, even more so given the declining trend in the chart. Students obviously have problems applying the knowledge they learn in the classroom. Several investigating points are important to check: Which courses prepared students for a particular job? How much training did students receive on co-op? Was this phenomenon universal to all the companies students worked for? The data available in the assessment database may help answer these questions by looking at students’ individual records. Since the database contains information on each company that employs students through the co-op system, the assessors will be able to identify the correlation between students’ performance and the companies they worked for. However, it is always safest to look at the historical data. Table 4.6 presents five years of records on employer evaluation of junior students. The focal point is Question 7, “Student applies classroom learning to work situations,” since the 2001 cohort did not show good results.
Table 4.6. Juniors’ Co-op Performance Evaluation

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
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<th>Q12</th>
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<th>Q14</th>
<th>Q15</th>
<th>Q16</th>
<th>Q17</th>
<th>Q18</th>
<th>Q19</th>
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<td>3.76</td>
<td>3.00</td>
<td>3.53</td>
<td>3.38</td>
<td>3.69</td>
<td>3.61</td>
<td>3.24</td>
<td>3.76</td>
<td>3.92</td>
<td>3.76</td>
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<td>2.92</td>
<td>4.00</td>
<td>4.07</td>
<td>4.00</td>
<td>4.36</td>
<td>4.15</td>
<td>4.46</td>
<td>4.40</td>
</tr>
<tr>
<td>1998</td>
<td>3.3</td>
<td>3.76</td>
<td>2.61</td>
<td>3.00</td>
<td>3.61</td>
<td>2.07</td>
<td>3.81</td>
<td>2.61</td>
<td>3.07</td>
<td>3.46</td>
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<td>4.30</td>
<td>4.23</td>
<td>3.69</td>
<td>2.38</td>
<td>2.30</td>
</tr>
<tr>
<td>1999</td>
<td>3.50</td>
<td>2.50</td>
<td>3.58</td>
<td>3.00</td>
<td>3.50</td>
<td>2.91</td>
<td>3.75</td>
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<td>4.00</td>
<td>3.58</td>
<td>3.33</td>
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<tr>
<td>2000</td>
<td>3.76</td>
<td>2.61</td>
<td>3.61</td>
<td>3.38</td>
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<td>2001</td>
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<td>2.78</td>
<td>2.61</td>
<td>3.53</td>
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<td>4.15</td>
<td>2.69</td>
<td>3.07</td>
<td>3.53</td>
<td>3.07</td>
<td>3.38</td>
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<td>3.69</td>
<td>2.3</td>
<td>4.07</td>
<td>2.31</td>
<td>4.08</td>
</tr>
</tbody>
</table>

This information is illustrated in Figure 4.12. The results show that juniors of academic year 2001 did not apply their classroom knowledge to their work well.

Figure 4.12. Employer Evaluation of Juniors’ Ability to Apply Classroom Learning to Work Situations – Five Years Summary
Students’ opinions about a company and their experience at a particular company are important as well. Students’ opinions about their experience with the company are conveyed in the students’ co-op survey. The report is extracted directly from the database. Figure 4.13 shows that for the generation of juniors in 2001, the co-op experience was overwhelmingly positive. This means that the students have been exposed to relevant assignments in the workplace.

Further investigation of each student’s work performance may show who exactly did live up to expectations. Figure 4.14 is an example of one student’s performance during three years of co-op. This may help narrow down the number of possible reasons why the overall score is not satisfactory for the employers.

![Report 2b. Students’ Co-op Survey for Given Generation for Given Academic Year](image)

Figure 4.13. Student Evaluation of Work Experience
Figure 4.14. Evaluation of Student’s Work Performance by Employers

Given that the employer report was not satisfactory and that students did not have any significant complaints, it would be valuable to have additional comments from the employers about how, specifically, the program should prepare its students before they come to co-op.

Students’ exit surveys have shown that the seniors had very positive experiences with the IME program (Figure 4.15). It is evident from the diagram that seniors collectively have a good experience with the IME program. However, they think they did not gain good communication skills. Question 10 is about building speaking and writing skills, and it has the lowest value in the chart.
The database is also designed to produce a report on students’ exit surveys for the last five years (see Figure 4.16). The last component of the assessment is the survey of alumni who graduated five years earlier. The results are better than expected. Figure 4.17 shows that the IME program is excellent, according to graduates who participated in the survey.
Figure 4.16. Student Exit Survey Summary Report

Figure 4.17. Alumni Survey for Academic Year 2001 (Students Admitted in 1991)

However, it is obvious from data collected in the last five years that this may not be very reliable information. Figure 4.18 shows that there is no consensus on how alumni look at their program five years after graduation. Moreover, significant research has been
done on alumni assessment, and the results show neither positive nor negative influence on curriculum development [128, 126].

![Diagram](image_url)

Figure 4.18. Alumni Survey for the Last Five Years (Students Admitted in 1987, 1988, 1989, 1990, and 1991)
4.2. Improve and Control

It is important to restate a few important facts about Six Sigma methodology. Six Sigma is a process of quality improvement that is dependent upon statistical analysis. The goal is to achieve product (or service) improvement by eliminating defects in the processes.

Experts use Six Sigma tools together with traditional statistical methods, especially with statistical software, to improve quality, reduce cost, and shorten time cycles in manufacturing settings. However, in manufacturing it is fairly easy to identify what is not working right. It is much more difficult to quantify service-oriented processes, which are intangible and can be driven by personal style (e.g., lecture delivery in the classroom). These processes can be changed quickly, unlike manufacturing processes. Courses can be added to the curriculum or reorganized to fit students’ needs and industry demands. Rules can be changed and strengthened if necessary. Teaching techniques can be adjusted and enriched by new ideas. Many changes come from individual or single assessment tools, such as focus groups, and if there are a number of those the overall impact can be tremendous. This happens because there is a lack of hard data on the performance of service processes. Despite these challenges, this assessment model seems to provide results that can be relied upon to assess and improve an educational program.

In a manufacturing environment, it is very important to obtain information that can be used to provide basics for any process improvement. Measurement in manufacturing has become a multibillion-dollar industry [100]. This generic assessment model is
valuable because it makes it possible to translate very vague specifications of educational processes into clear performance factors and measures throughout educational programs and entire engineering colleges.

The implementation phase is a very delicate step in educational settings, which are very different from any other service industry, and even more different from the manufacturing sector. In an educational environment each element of the process possesses a certain amount of freedom (e.g., teaching style, ability to explore and challenge boundaries in any area of education, respect for the uniqueness and individuality of each student). Therefore, the variability will never be eliminated. The challenge is how to reduce it. An important aspect of this problem is the fact that the data collected and analyzed here is not ready for advanced analysis. It will take three to four years for assessors and management to rely more on sophisticated statistical analysis of educational processes [99, 100].

In the Six Sigma world, management — especially top management — must take time to consider all the consequences of variations and the real cost of eliminating, or at least minimizing, variation. For an engineering college, that means that the professors involved in the assessment — supported by the director of the program, the department head, and the dean of the college — initiate the improvement process, set up the standards, and closely monitor the changes that occur. There are several questions in front of them: What is wrong? Which process has suffered? Where to look? When? How
big is the problem? What is the impact on the system? What are the benefits of action? What are the consequences of inaction?

The data collection and the amount of information gathered are enormous. It is very important to distinguish important problems from marginal problems that may arise from the effort to find real gaps and opportunities for improvement. Here is the summary of the assessment for the IME program:

1. Seniors’ performance in the 2001 academic year in INDS512, Applied Regression Analysis, was significantly lower than in the rest of the courses. The weakest point was students’ ability to apply math skills. This problem has been noted in the past as well.

2. Senior students of 2001 had trouble using information technology and systems in the area of regression analysis.

3. All three generations of students that went to co-op in the 2001 academic year showed poor communication skills (writing skills and presentation skills) as well as an inability to apply classroom learning to work situations.

Working closely with the faculty and students, the assessment team will be able to set ground rules for improvement. It would be good to introduce additional assessment methods and tools to monitor and control the changes more closely. These new methods and tools could help the assessment process overall if implemented properly and in such way that they do not interfere with students’ learning process.
On the other hand, it is important to control the processes that are satisfactory after the first assessment cycle so that they stay satisfactory. The goal is not only to meet program outcomes requirements but also to stabilize the processes identified within an educational program. To keep a process stable, every step of the improvement and control phase must be documented.
Conclusion

Quality education is the most critical factor in the marketplace success of any institution of higher learning. A superior approach to this end is the application of Six Sigma methodology to continuously improve the quality of engineering education. The model presented here is a comprehensive guide to the real-world application of Six Sigma methodology in academia, and it may be applied to any engineering college to improve student, faculty, and system performance. It is also designed to help any engineering college program to clearly identify indicators of whether the program is achieving its goals by incorporating a well-formulated feedback assessment process into ABET EC 2000 accreditation requirements. The significant benefits of the model are its comprehensive data collection, data manipulation, and methods of analysis, as well as its development of the faculty role in the process of an engineering college's continuous quality improvement process.
Future Research

Six Sigma methodology is great at surgically reducing costs and improving productivity across all business functions and workflows. Service industries, from health care to financial services, have already launched Six Sigma programs. “Universities today are facing much the same market situation industry has faced for decades. The introduction of new communication technologies, such as the Internet, teleconferencing, and satellite communication, has shrunk the world. Distance education globalizes both the supply and demand of educational services. Competition among academic institutions for students, faculty, and financial support is increasing. Quality of education is becoming a subject of major concern.” [71]. The cost of high-quality education is constantly increasing, which as a consequence brings higher tuition fees. The vast majority of universities today practice some form of quality management. Even the Malcolm Baldrige National Quality Award now has education criteria for performance excellence for educational institutions. However, without a methodical approach to continuously improving quality and profitability, and a focus on the college system, these efforts may not succeed.

The basic idea behind Six Sigma is to achieve product perfection by eliminating defects in the business processes that create the product. To reach Six Sigma, a process must generate no more than 3.4 errors per million opportunities. However, near-perfection is
not what we are searching for in educational settings. The goals are to apply Six Sigma principles in engineering education to mold best quality, ensure flexibility of engineering programs, and use the best approach to serving students’ needs, which would further ensure profitability and strong competitive advantage for the institution. There are several areas relevant to future research in continuous quality improvement of engineering education:

- The emergence and growth of cutting-edge technologies, like wireless communications, micro- and nano-electronics, space exploration, molecular biology, and genetic engineering, have been calling for a larger and better prepared cadre of engineers and scientists with very distinctive characteristics. However, for universities to be successful in their response to new social demands, the incoming students must possess the necessary foundations in mathematics and science. Future research should focus more on freshmen and their ability to enter the engineering and science ambience of an engineering college. It should address the impact of first year students’ insufficient knowledge of mathematics and science on students’ overall performance in college. Is it necessary for an engineering college to start preparing its students for engineering as a postsecondary career decision while they are still in high school?

- So far academicians assume that what they deliver translates to learning. An engineering college should analyze the delivery mechanisms in place so that
they ensure high-quality education. Future research should explore the use of new technologies and students’ performance in context with students’ learning abilities. Verbal interaction between instructors and students in simultaneous two-way audio and video distance education settings is just one example. Are there ways to differentiate among different models of delivery?

- Data collection from surveys, exams, portfolios, and GPAs seems to be the trend for ABET assessors. Future research should include other factors such as students’ learning capability, using indicators like the Myers-Briggs Indicator and Kolb’s Learning Style Inventory; students’ social support; students’ vision of their future — their social status; and students’ sociological characteristics that have never been used for admissions or performance.

- Future research should explore a comprehensive modeling palette of the Design of Experiments and Regression Analysis tools to identify other important factors that determine learning outcomes.
References


137. Wheeler James M. “Getting Started: Six-Sigma Control of Chemical Operations.” *Chemical Engineering Progress* 98, no.6 (June, 2002): 76-81.


Appendix A

SQL Code
**SQL Code**

**Query 1 — Portfolio**

Portfolio evaluation of all the courses taken by a particular student.

Input data: SSN

```sql
SELECT Portfolio.SSNo, Portfolio.*
FROM Portfolio
WHERE ((Portfolio.SSNo)=[Give the SS No]);
```

**Query 2.1 — Co-op Student Survey**

Co-op student survey. Per particular generation (sophomore, pre-junior, or junior) for the last five years.

Input data: Year of education

```sql
SELECT Co-op Survey.StudentYear, Co-op Survey.*
FROM Co-op Survey
WHERE (((Co-op Survey.StudentYear)=[Year of Education]));
```
Query 2.12 — Student Co-op Survey

Student co-op survey for particular education year and academic year.
Input data: year of education; academic year

```
SELECT co-op Survey.StudentYear, Co-op Survey.DateYear, Co-op Survey.*
FROM Co-op Survey
WHERE (((Co-op Survey.StudentYear)=[Give Education Year]) AND ((Co-op
Survey.DateYear)=[Give Date Year]));
```

Query 2.2 — Student Co-op Survey

Student co-op survey of all students in co-op for particular academic year.
Input data: academic year

```
SELECT Co-op Survey.DateYear, Co-op Survey.*
FROM Co-op Survey
WHERE (((Co-op Survey.DateYear)=[Give the Date Year]));
```

Query 3 — Portfolio

Course performance average for particular academic year and educational year
Input data: academic year; educational year

```
SELECT Portfolio.Year, Portfolio.*, Courses.StudentYear, Courses.*
FROM Courses INNER JOIN Portfolio ON Courses.CourseNo = Portfolio.CourseNo
```
WHERE (((Portfolio.Year)=[Give Date Year]) AND ((Courses.StudentYear)=[Give Student Year]));

**Query 40 — Portfolio**

Course performance for particular academic year

Input data: academic year

```
SELECT Portfolio.Year, Portfolio.*
FROM Portfolio
WHERE (((Portfolio.Year)=[Give the Year]));
```

**Query 41 — Portfolio**

Particular course performance for particular education year and average

Input data: course number; education year

```
SELECT Portfolio.CourseNo, Portfolio.*
FROM Portfolio
WHERE (((Portfolio.CourseNo)=[Give the course No]));
```

**Query 60 — Student Exit Survey**

Student exit interview for particular academic year

Input data: academic year
SELECT StudentExitSurvey.Year, StudentExitSurvey.*
FROM StudentExitSurvey
WHERE (((StudentExitSurvey.Year)=[Give the year]));

Query 70 — Alumni Survey
Alumni survey conducted in particular academic year
Input data: academic year

SELECT AlumniSurvey.Year, AlumniSurvey.*
FROM AlumniSurvey
WHERE (((AlumniSurvey.Year)=[Give the Year]));

Query 90 — Employer Survey
Employer survey for particular student
Input data: SSN

SELECT EmployerSurvey.SSNo, EmployerSurvey.*
FROM EmployerSurvey
WHERE (((EmployerSurvey.SSNo)=[Give Student No]));

Query 91 — Employer Survey
Employer survey for particular student generation (sophomore, pre-junior, or junior)
Input data: educational year
SELECT EmployerSurvey.StudentYear, EmployerSurvey.*
FROM EmployerSurvey
WHERE (((EmployerSurvey.StudentYear)=[Give Education Year]));

Query 92 — Employer Survey
Employer survey for particular student academic year
Input data: academic year

SELECT EmployerSurvey.DateYear, EmployerSurvey.*
FROM EmployerSurvey
WHERE (((EmployerSurvey.DateYear)=[Give the date Year]));

Query 93 — Employer Survey
Employer survey for particular student education year
Input data: education year

SELECT EmployerSurvey.StudentYear, EmployerSurvey.*
FROM EmployerSurvey
WHERE (((EmployerSurvey.StudentYear)=[Give Education Year]));

Query 94 — Employer Survey
Particular student survey from each employer
Input data: SSN

SELECT EmployerSurvey.SSNo, EmployerSurvey.*
FROM EmployerSurvey
WHERE (((EmployerSurvey.SSNo)=\[Give SS No\]));

**Query Student Exit Generation**

Insert: year of admission

SELECT Personal1.YearOfAdmission, StudentExitSurvey.EQuestion2,
        StudentExitSurvey.EQuestion3, StudentExitSurvey.EQuestion4,
        StudentExitSurvey.EQuestion5, StudentExitSurvey.EQuestion6,
        StudentExitSurvey.EQuestion7, StudentExitSurvey.EQuestion8,
        StudentExitSurvey.EQuestion9, StudentExitSurvey.EQuestion10,
        StudentExitSurvey.EQuestion11, StudentExitSurvey.EQuestion12,
        StudentExitSurvey.EQuestion13, StudentExitSurvey.EQuestion14,
        StudentExitSurvey.EQuestion15, StudentExitSurvey.EQuestion16,
        StudentExitSurvey.EQuestion17, StudentExitSurvey.EQuestion18,
        StudentExitSurvey.EQuestion19, StudentExitSurvey.EQuestion20,
        StudentExitSurvey.EQuestion21, StudentExitSurvey.EQuestion22,
        StudentExitSurvey.EQuestion23, StudentExitSurvey.EQuestion24,
        StudentExitSurvey.EQuestion25a, StudentExitSurvey.EQuestion25b,
SELECT Personal1.YearOfAdmission, Avg(StudentExitSurvey.EQuestion4) AS AvgOfEQuestion4, Avg(StudentExitSurvey.EQuestion5) AS AvgOfEQuestion5, Avg(StudentExitSurvey.EQuestion6) AS AvgOfEQuestion6, Avg(StudentExitSurvey.EQuestion7) AS AvgOfEQuestion7, Avg(StudentExitSurvey.EQuestion8) AS AvgOfEQuestion8, Avg(StudentExitSurvey.EQuestion9) AS AvgOfEQuestion9, Avg(StudentExitSurvey.EQuestion10) AS AvgOfEQuestion10, Avg(StudentExitSurvey.EQuestion11) AS AvgOfEQuestion11, Avg(StudentExitSurvey.EQuestion12) AS AvgOfEQuestion12, Avg(StudentExitSurvey.EQuestion13) AS AvgOfEQuestion13, Avg(StudentExitSurvey.EQuestion14) AS AvgOfEQuestion14, Avg(StudentExitSurvey.EQuestion15) AS AvgOfEQuestion15, Avg(StudentExitSurvey.EQuestion16) AS AvgOfEQuestion16, Avg(StudentExitSurvey.EQuestion17) AS AvgOfEQuestion17,
Query Student Co-op Performance

Particular student survey from each employer

Input data: SSN
FROM Co-op Survey
WHERE (((Co-op Survey.SSNo)=[GIVE STUDENT SS NO]));

Query Alumni Generation

Input data: year of graduation

FROM Personal1 INNER JOIN AlumniSurvey ON Personal1.[SS No] = AlumniSurvey.SSNo
WHERE (((Personal1.YearOfGraduation)=[Alumni: Give Year of Graduation]));

**Query Alumni Generation — Average**

Input data: year of admission

FROM Personal1 INNER JOIN AlumniSurvey ON Personal1.[SS No] = AlumniSurvey.SSNo
GROUP BY Personal1.YearOfAdmission
HAVING (((Personal1.YearOfAdmission)=[Alumni: Give Year of Admission]));

**Query Two-Year Alumni Generation — Average**

Input data: year of admission
SELECT Personal1.YearOfAdmission, AlumniSurvey.TakenPreviously,
Avg(AlumniSurvey.AQuestion5) AS AvgOfAQuestion5, Avg(AlumniSurvey.AQuestion6)
AS AvgOfAQuestion6, Avg(AlumniSurvey.AQuestion7) AS AvgOfAQuestion7,
Avg(AlumniSurvey.AQuestion8) AS AvgOfAQuestion8, Avg(AlumniSurvey.AQuestion9)
AS AvgOfAQuestion9, Avg(AlumniSurvey.AQuestion10) AS AvgOfAQuestion10,
Avg(AlumniSurvey.AQuestion11) AS AvgOfAQuestion11,
Avg(AlumniSurvey.AQuestion12) AS AvgOfAQuestion12,
Avg(AlumniSurvey.AQuestion13) AS AvgOfAQuestion13,
Avg(AlumniSurvey.AQuestion14) AS AvgOfAQuestion14
FROM Personal1 INNER JOIN AlumniSurvey ON Personal1.[SS No] =
AlumniSurvey.SSNo
GROUP BY Personal1.YearOfAdmission, AlumniSurvey.TakenPreviously
HAVING (((Personal1.YearOfAdmission)=[Alumni: Give Year of Admission]) AND
((AlumniSurvey.TakenPreviously)=No));

Query Five-Year Alumni Generation — Average

Input data: year of admission

SELECT Personal1.YearOfAdmission, AlumniSurvey.TakenPreviously,
Avg(AlumniSurvey.AQuestion5) AS AvgOfAQuestion5, Avg(AlumniSurvey.AQuestion6)
AS AvgOfAQuestion6, Avg(AlumniSurvey.AQuestion7) AS AvgOfAQuestion7,
Avg(AlumniSurvey.AQuestion8) AS AvgOfAQuestion8, Avg(AlumniSurvey.AQuestion9)
AS AvgOfAQuestion9, Avg(AlumniSurvey.AQuestion10) AS AvgOfAQuestion10,
Avg(AlumniSurvey.AQuestion11) AS AvgOfAQuestion11,
Avg(AlumniSurvey.AQuestion12) AS AvgOfAQuestion12,
Avg(AlumniSurvey.AQuestion13) AS AvgOfAQuestion13,
Avg(AlumniSurvey.AQuestion14) AS AvgOfAQuestion14
FROM Personal1 INNER JOIN AlumniSurvey ON Personal1.[SS No] =
AlumniSurvey.SSNo
GROUP BY Personal1.YearOfAdmission, AlumniSurvey.TakenPreviously
HAVING (((Personal1.YearOfAdmission)=[Alumni: Give Year of Admission]) AND
((AlumniSurvey.TakenPreviously)=Yes));

Query Student Co-op Generation

Input data: year of admission

SELECT Personal1.YearOfAdmission, Co-op Survey.COQuestion1, Co-op
Survey.COQuestion2, Co-op Survey.COQuestion3, Co-op Survey.COQuestion4, Co-op
Survey.COQuestion5, Co-op Survey.COQuestion6, Co-op Survey.COQuestion7, Co-op
Survey.COQuestion8, Co-op Survey.COQuestion9, Co-op Survey.COQuestion10, Co-op
Survey.COQuestion11, Co-op Survey.COQuestion12, Co-op Survey.COQuestion13,
Co-op Survey.COQuestion14, Co-op Survey.COQuestion15, Co-op
Survey.COQuestion16, Co-op Survey.COQuestion17, Co-op Survey.COQuestion18,
Co-op Survey.COQuestion19
FROM Personal1 INNER JOIN Co-op Survey ON Personal1.[SS No] = Co-op Survey.SSNo

WHERE (((Personal1.YearOfAdmission)=[Co op: give Year of Admission]));

**Query Student Co-op Generation — Average**

Input data: year of admission

FROM Personal1 INNER JOIN Co-op Survey ON Personal1.[SS No] = Co-op Survey.SSNo
GROUP BY Personal1.YearOfAdmission
HAVING (((Personal1.YearOfAdmission)= [Co op: give Year of Admission]));

**Query Employer Co-op Generation**

Input data: year of admission

SELECT Personal1.YearOfAdmission, EmployerSurvey.COQuestion1,
EmployerSurvey.COQuestion2, EmployerSurvey.COQuestion3,
EmployerSurvey.COQuestion4, EmployerSurvey.COQuestion5,
EmployerSurvey.COQuestion6, EmployerSurvey.COQuestion7,
EmployerSurvey.COQuestion8, EmployerSurvey.COQuestion9,
EmployerSurvey.COQuestion10, EmployerSurvey.COQuestion11,
EmployerSurvey.COQuestion12, EmployerSurvey.COQuestion13,
EmployerSurvey.COQuestion14, EmployerSurvey.COQuestion15,
EmployerSurvey.COQuestion16, EmployerSurvey.COQuestion17,
EmployerSurvey.COQuestion18, EmployerSurvey.COQuestion19
FROM Personal1 INNER JOIN EmployerSurvey ON Personal1.[SS No] =
EmployerSurvey.SSNo
WHERE (((Personal1.YearOfAdmission)= [Employer: Give Year of Admission]));
Query Employer Co-op Generation — Average

Input data: year of admission

FROM Personal1 INNER JOIN EmployerSurvey ON Personal1.[SS No] = EmployerSurvey.SSNo
GROUP BY Personal1.YearOfAdmission
HAVING (((Personal1.YearOfAdmission)=[Employer: Give Year of Admission]));

Query Employer Co-op — Average for Last Five Years

SELECT Personal1.YearOfAdmission, Avg(EmployerSurvey.COQuestion1) AS AvgOfCOQuestion1, Avg(EmployerSurvey.COQuestion2) AS AvgOfCOQuestion2,
      Avg(EmployerSurvey.COQuestion3) AS AvgOfCOQuestion3,
      Avg(EmployerSurvey.COQuestion4) AS AvgOfCOQuestion4,
      Avg(EmployerSurvey.COQuestion5) AS AvgOfCOQuestion5,
      Avg(EmployerSurvey.COQuestion6) AS AvgOfCOQuestion6,
      Avg(EmployerSurvey.COQuestion7) AS AvgOfCOQuestion7,
      Avg(EmployerSurvey.COQuestion8) AS AvgOfCOQuestion8,
      Avg(EmployerSurvey.COQuestion9) AS AvgOfCOQuestion9,
      Avg(EmployerSurvey.COQuestion10) AS AvgOfCOQuestion10,
      Avg(EmployerSurvey.COQuestion11) AS AvgOfCOQuestion11,
      Avg(EmployerSurvey.COQuestion12) AS AvgOfCOQuestion12,
      Avg(EmployerSurvey.COQuestion13) AS AvgOfCOQuestion13,
      Avg(EmployerSurvey.COQuestion14) AS AvgOfCOQuestion14,
      Avg(EmployerSurvey.COQuestion15) AS AvgOfCOQuestion15,
      Avg(EmployerSurvey.COQuestion16) AS AvgOfCOQuestion16,
Avg(EmployerSurvey.COQuestion17) AS AvgOfCOQuestion17,
Avg(EmployerSurvey.COQuestion18) AS AvgOfCOQuestion18,
Avg(EmployerSurvey.COQuestion19) AS AvgOfCOQuestion19
FROM Personal1 INNER JOIN EmployerSurvey ON Personal1.[SS No] = EmployerSurvey.SSNo
GROUP BY Personal1.YearOfAdmission;

**Query Portfolio, Particular Generation and Particular Academic Year**

Input data: academic year and year of education

SELECT Courses.StudentYear, Portfolio.Year, Courses.CourseNo, Portfolio.PF1, Portfolio.PF2, Portfolio.PF3, Portfolio.PF4, Portfolio.PF5, Portfolio.PF6, Portfolio.PF7, Portfolio.PF8
FROM Courses INNER JOIN Portfolio ON Courses.CourseNo = Portfolio.CourseNo
WHERE (((Courses.StudentYear)=[Give the Student Year]) AND ((Portfolio.Year)=[Give the dateYear]));

**Query Portfolio, Particular Admission Year**

Input data: year of admission

SELECT Personal1.YearOfAdmission, Portfolio.PF1, Portfolio.PF2, Portfolio.PF3, Portfolio.PF4, Portfolio.PF5, Portfolio.PF6, Portfolio.PF7, Portfolio.PF8
FROM Personal1 INNER JOIN Portfolio ON Personal1.[SS No] = Portfolio.SSNo
WHERE (((Personal1.YearOfAdmission)=[PortFolio: Give Year of Admission]));

**Query Portfolio, Particular Admission Year — Average**

Input data: year of admission

SELECT Personal1.YearOfAdmission, Avg(Portfolio.PF1) AS AvgOfPF1,
Avg(Portfolio.PF2) AS AvgOfPF2, Avg(Portfolio.PF3) AS AvgOfPF3, Avg(Portfolio.PF4)
AS AvgOfPF4, Avg(Portfolio.PF5) AS AvgOfPF5, Avg(Portfolio.PF6) AS AvgOfPF6,
Avg(Portfolio.PF7) AS AvgOfPF7, Avg(Portfolio.PF8) AS AvgOfPF8
FROM Personal1 INNER JOIN Portfolio ON Personal1.[SS No] = Portfolio.SSNo
GROUP BY Personal1.YearOfAdmission
HAVING (((Personal1.YearOfAdmission)=[PortFolio: Give Year of Admission]));
Appendix B

List of Reports
List of Reports

1. Report on Student’s Coursework

This report is about a particular student’s coursework assessed through appropriate portfolio elements. For a given Social Security number the report will display all the courses taken by that student. Since each course is assessed for all appropriate portfolio aspects (listed below this report), it is possible to see progress in each area independently. As a result the student will be able to strengthen his or her weakest skills by focusing his or her efforts on the assignments in those courses.

Report 1. Coursework by Particular Student

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</table>
PF I: Skills in Calculus, Physics, Chemistry and Electronics  
PF II: Writing and Communication Skills  
PF III: Engineering Design Skills  
PF IV: Information Systems and Technology Skills  
PF V: Engineering Measurement Skills  
PF VI: Management Skills  
PF VII: Economics Skills  
PF VIII: Skills in Engineering Science

2. Report of Students’ Co-op Survey for a Given Generation for the Last Five Years

Report 2 is about a particular generation of students and their experience on co-op (sophomore, pre-junior, junior), viewed through survey answers students provide after they complete the co-op. The report exposes students’ satisfaction and dissatisfaction with the co-op learning experience. It also shows which companies did not accommodate students with certain elements of the learning experience. The report gives assessors an option to view students’ co-op experience by a certain generation of students through five consecutive years.
### Report 2. Students’ Co-op Survey for a Given Generation for the Last Five Years

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<th>Q4</th>
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</table>

### 2a. Report of Students’ Co-op Survey for a Given Generation for the Last Five Years — Average

Report 2a gives the average value for the survey in each of the five years for a particular student generation (e.g., juniors) about the students’ co-op experience. It also gives an overall average value for all five years of evaluation for a particular student generation.

### Report 2a. Students’ Co-op Survey for a Given Generation for the Last Five Years

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<th>Generation of Students</th>
<th>Date Year</th>
<th>Q1</th>
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<th>Q3</th>
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<th>Q5</th>
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<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
<th>Q13</th>
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2b. Report of Students’ Co-op Survey for a Given Generation for a Given Academic Year

This is the same report as Report 2, except that this report extracts more precise information. The information presented is about students’ co-op experience for specific generation and specific academic year.

| Report 2b. Students’ Co-op Survey for Given Generation for Given Academic Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generation Date of Students Year | SSN | Employer | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 |
| Junior | 2001 | | | | | | | | | | | | | | | | | | | |
| 1 | 1130 | Company 14 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 |
| 2 | 3230 | Company 13 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 5 |
| 3 | 1122 | Company 12 | 4 | 4 | 3 | 5 | 3 | 4 | 4 | 4 | 3 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 |
| 4 | 1144 | Company 11 | 5 | 4 | 3 | 4 | 4 | 3 | 5 | 4 | 3 | 4 | 5 | 3 | 4 | 5 | 5 | 4 | 5 | 4 | 4 |
| 5 | 2222 | Company 10 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 5 |
| 6 | 5556 | Company 9 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 5 |
| 7 | 9996 | Company 14 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 |
| 8 | 1155 | Company 13 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 |
| 9 | 7777 | Company 12 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| 10 | 1111 | Company 11 | 4 | 3 | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 5 | 3 | 4 | 3 | 5 | 4 | 3 | 4 | 4 | 5 |
| 11 | 4444 | Company 10 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 6 | 3 | 4 | 2 | 2 | 4 | 3 | 3 | 6 | 5 | 5 |
| 12 | 8888 | Company 9 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 5 | 5 | 6 | 5 | 6 | 5 |
| 13 | 8850 | Company 13 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |

2c. Report of Students’ Co-op Survey for a Given Generation for a Given Academic Year — Average

| Report 2c. Students’ Co-op Survey for a Given Generation for a Given Academic Year — Average |
| Generation Date of Students Year | Data Year | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 |
| Junior | 2001 | | | | | | | | | | | | | | | | | | | | |
| Average | 3.76 | 3.6 | 3.54 | 3.36 | 3.69 | 3.62 | 3.85 | 3.17 | 3.92 | 3.77 | 3.62 | 3.04 | 4.00 | 4.08 | 4.00 | 4.38 | 4.15 | 4.96 | 4.31 |

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3. Report of Students’ Coursework for a Given Generation for a Given Academic Year — Average

This report is a portfolio evaluation of students’ coursework. It is a summary of a given generation (e.g., juniors) assessed in a given year. It provides information about that generation’s performance in each course in a given academic year. This portfolio evaluation allows assessors to look at different elements of students’ performance separately and compare them, which is essential for program outcomes evaluation. This allows assessors to easily identify areas of potential improvement.

Report 3. Students’ Coursework for a Given Generation for a Given Academic Year

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<th>Portfolio Report Generation Course</th>
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<tbody>
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<td>INCS411 (5 detail records)</td>
<td>2001</td>
<td>3.2</td>
<td>3.2</td>
<td>3.4</td>
<td>3.4</td>
<td>3.8</td>
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</tr>
<tr>
<td>Average</td>
<td>INCS436 (5 detail records)</td>
<td>3.8</td>
<td>3.6</td>
<td>3.6</td>
<td>3.8</td>
<td>3.8</td>
<td>3.3</td>
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</tr>
<tr>
<td>Average</td>
<td>INCS440 (6 detail records)</td>
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<td>4.2</td>
<td>4.2</td>
<td>3.8</td>
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<td>3.6</td>
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</tr>
<tr>
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<td>INCS453 (5 detail records)</td>
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<td>4.2</td>
<td>4.2</td>
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<td>3.6</td>
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<tr>
<td>Average</td>
<td>INCS463 (5 detail records)</td>
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<td>3.4</td>
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<td>3.6</td>
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<td></td>
</tr>
<tr>
<td>Average</td>
<td>INCS476 (5 detail records)</td>
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<td>3.8</td>
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</tr>
<tr>
<td>Average</td>
<td>INCS470 (5 detail records)</td>
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<td>4.4</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>INCS475 (5 detail records)</td>
<td>3.8</td>
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<td>3.6</td>
<td>3.8</td>
<td>3.6</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>Summary for “year” = 2001 (10 detail records)</td>
<td>3.43</td>
<td>3.09</td>
<td>3.9</td>
<td>3.67</td>
<td>3.94</td>
<td>3.5</td>
<td>3.4</td>
<td>3.86</td>
</tr>
</tbody>
</table>
4. Report on Portfolio Evaluation for a Given Course for the Last Five Years

Report 4 is the summary of students’ work, assessed through portfolio aspects, in a given course. It contains data on every student who has taken the course in the last five years. (For the purposes of illustration, only two years are displayed in the table below.) This information is valuable for the course evaluation. It provides information that may be useful to the instructor to improve his or her course and help students to achieve their goals in the course.

<table>
<thead>
<tr>
<th>Course</th>
<th>Year</th>
<th>PF1</th>
<th>PF2</th>
<th>PF3</th>
<th>PF4</th>
<th>PF5</th>
<th>PF6</th>
<th>PF7</th>
<th>PF8</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDS411</td>
<td>2000</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Average</td>
<td>Sum for ‘Year’ = 2000 (5 detail records)</td>
<td>3.2</td>
<td>3.2</td>
<td>3.4</td>
<td>3.4</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Average</td>
<td>Sum for ‘Year’ = 2001 (5 detail records)</td>
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<td>3.8</td>
<td>3.8</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Sum for ‘Portfolio Course N.’ = INDS411</td>
<td>3.5</td>
<td>3.7</td>
<td>3.6</td>
<td>3.6</td>
<td>3.8</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(25 detail records)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
5. Report on Students’ Exit Survey for the Last Five Years

Report 5 presents very straightforward information on seniors’ overall opinion about the program using the student exit interview as input data. For the best analysis averages for each question are calculated and displayed together with the data from the past years. Since the questions are directly related to IME program outcomes, it is relatively simple to detect the problems indicated by the graduates.

Report 5. Students’ Exit Survey for the Last Five Years

<table>
<thead>
<tr>
<th>Year</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
<th>Q13</th>
<th>Q14</th>
<th>Q15</th>
<th>Q16</th>
<th>Q17</th>
<th>Q18</th>
<th>Q19</th>
<th>Q20</th>
<th>Q21</th>
<th>Q22</th>
<th>Q23</th>
<th>Q24</th>
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<th>Q26</th>
<th>Q27</th>
<th>Q28</th>
<th>Q29</th>
<th>Q30</th>
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</thead>
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<td>1997</td>
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</tr>
<tr>
<td>1998</td>
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<td>1999</td>
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<td>3.0</td>
<td>3.0</td>
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</tr>
<tr>
<td>2001</td>
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<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
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<td></td>
</tr>
</tbody>
</table>

5a. Report on Students’ Exit Survey for a Given Academic Year

This report is developed in order to review a specific academic year.

Report 5a. Students’ Exit Survey for Given Academic Year

| Year       | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 | Q21 | Q22 | Q23 | Q24 | Q25 | Q26 | Q27 | Q28 | Q29 | Q30 |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 2001       | 5.0 | 3.2 | 3.1 | 4.2 | 3.3 | 3.2 | 3.3 | 4.2 | 3.3 | 3.2 | 3.1 | 4.2 | 3.3 | 3.2 | 3.3 | 4.2 | 3.3 | 3.2 | 3.1 | 4.2 | 3.3 | 3.2 | 3.3 | 4.2 | 3.3 | 3.2 | 3.1 |

Summary for ‘Student Exit Survey Year’ = 2001 (15 detail records)
5b. Report on Students’ Exit Survey for Specific Year of Admission

This report is developed in order to review a specific year of admission. Unlike Report 5a, in which the assessors may be interested to find out results of the student exit survey in a specific academic year, this report helps search for a specific generation of seniors.

Report 5b. Student Exit Survey for a Given Year of Admission

<table>
<thead>
<tr>
<th>Year of Admission: 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28</td>
</tr>
</tbody>
</table>

Average: 3.6 4.2 4.3 3.5 4.4 3.8 4.5 3.5 3.3 4.3 4.2 4.1 3.7 4.3 3.3 4.2 4.3 4.4 4.5 3.3 3.5

6. Report on Alumni Survey Results for the Last Five Years

Like Report 5, this report presents specific and apparent information about alumni evaluation of the program. The questions of the survey are directly related to IME program objectives. Therefore, it is easy to draw some important conclusions about what necessary changes the assessment committee needs to undertake. To follow the progress of the program over a certain period of time, evaluators are also provided with several years of alumni program appraisal.
### 6a. Report on Alumni Survey Results for a Given Academic Year

#### Report 6a. Alumni Survey for a Given Academic Year

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
<th>Q13</th>
<th>Q14</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>4.14</td>
<td>3.85</td>
<td>3.47</td>
<td>4.09</td>
<td>4.09</td>
<td>3.23</td>
<td>3.47</td>
<td>4.28</td>
<td>2.78</td>
<td>3.28</td>
</tr>
</tbody>
</table>

*Summary for Alumni Survey Year = 2001 (21 detail records)*

### 6b. Report on Alumni Survey Results for a Given Year of Admission

#### Report 6b. Alumni Survey for a Given Year of Admission

<table>
<thead>
<tr>
<th>Year of Admission</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
<th>Q13</th>
<th>Q14</th>
</tr>
</thead>
</table>

*Summary for Alumni Survey Year = 1990 (57 detail records)*
7. Report on Students’ Co-op Performance Based on Employers’ Evaluation for a Given Academic Year

This report reflects students’ overall performance at co-op for a given year. It is a very important report, because it shows the student co-op population for that year and its performance. The questions are directly related to IME program and ABET outcomes, and so are the areas of potential improvement in co-op curriculum.

### Report 7. Students’ Co-op Performance: Employer Evaluation for All Generations in a Given Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
<th>Q13</th>
<th>Q14</th>
<th>Q15</th>
<th>Q16</th>
<th>Q17</th>
<th>Q18</th>
<th>Q19</th>
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</thead>
<tbody>
<tr>
<td>2001</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.20</td>
<td>2.78</td>
<td>2.01</td>
<td>1.53</td>
<td>2.89</td>
<td>2.49</td>
<td>2.67</td>
<td>2.10</td>
<td>1.90</td>
<td>1.88</td>
<td>1.87</td>
<td>1.93</td>
<td>1.83</td>
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<td>2.10</td>
<td>2.30</td>
<td>4.07</td>
<td>2.91</td>
<td>4.38</td>
</tr>
<tr>
<td>Summary for “Employer Report” = Junior (13 detail records)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.58</td>
<td>3.06</td>
<td>3.51</td>
<td>3.5</td>
<td>3.68</td>
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<td>3.77</td>
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<td>3.77</td>
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<tr>
<td>Summary for “Employer Report” = Sophomore (13 detail records)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>2.38</td>
<td>1.92</td>
<td>2.58</td>
<td>3.47</td>
<td>3.46</td>
<td>3.46</td>
<td>3.55</td>
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<td>3.46</td>
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<td>3.46</td>
<td>3.46</td>
<td>3.46</td>
<td>3.46</td>
</tr>
<tr>
<td>Summary for “Employer Report” = Junior (13 detail records)</td>
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</tr>
</tbody>
</table>

7a. Report on Students’ Co-op Performance Based on Employers’ Evaluation for a Given Generation in the Last Five Years

Even greater help to evaluators is the report on students’ co-op performance based on a particular generation. Performance of juniors, for example, monitored through a certain period of time, shows whether the changes that have been implemented actually work. It also gives some clues about where problems are and how to fix them.
7b. **Report on Student’s Co-op Performance Based on Employers’ Evaluations**

This report gives a closer look at a particular student’s co-op work. The progress he or she makes year after year is well documented here and can provide very detailed inputs about certain problems. It also helps an adviser guide the student on what to improve and how to improve it.

### Report 7b. Student’s Co-op Performance Based on Employers’ Evaluation

<table>
<thead>
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<th>SSN</th>
<th>Semester</th>
<th>Quarter</th>
<th>Year</th>
<th>Employer Name</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
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<th>Q14</th>
<th>Q15</th>
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<td>7717000</td>
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**Average:** 3.33 2.66 3.3 3.6 3.3 4.3 3.3 4.3 3.6 4.3 3.3 4.3 3.8 4 3.5 4 4
8. Report on IME Program Outcomes for Students' Portfolio

Portfolio IME Program Outcomes for a Particular Generation

Portfolio Assessment for Generation Admission Year: 2001

<table>
<thead>
<tr>
<th>IME outcome</th>
<th>Value</th>
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<tbody>
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<tr>
<td>(k)</td>
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# 9. Report on IME Program Outcomes for Overall Co-op Students’ Performance

**IME Program Outcomes for Students’ Overall Co-op Performance for a Particular Generation**

*Co-op Assessment for Generation Admission Year 2001*

<table>
<thead>
<tr>
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10. Report on IME Program Outcomes for Students' Exit Survey

**IME Program Outcomes for Students’ Exit Survey for a Particular Generation**

*Students' Exit Assessment for Generation Admission Year 2001*

<table>
<thead>
<tr>
<th>IME outcome (a)</th>
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### 11. Report on IME Program Outcomes for Alumni Survey

#### IME Program Outcomes for Alumni Survey for a Particular Generation

*Alumni Assessment for Generation Year of Graduation: 2001*

<table>
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**IME Program Outcomes**

*for Academic Year: 2001*

<table>
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<td>3.39</td>
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<td>(k)</td>
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Appendix C

Industrial and Manufacturing Engineering Program

Curriculum
Industrial and Manufacturing Engineering Program
Curriculum

<table>
<thead>
<tr>
<th>Undergraduate Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>20INDS100. Introduction to Industrial Engineering.</strong> 2 cr. An overview of industrial engineering, its basic concepts, and applications. This team-taught course examines industrial engineering’s development and current challenges, as well as trends for the future. 2 lec.</td>
</tr>
<tr>
<td>• <strong>20INDS322. Numerical Methods I.</strong> 3 cr. Introduction to the various algorithms, method used to solve engineering oriented problems. 3 lec.</td>
</tr>
<tr>
<td>• <strong>20INDS354. Manufacturing Processes I.</strong> 3 cr. Discussion of the principles and methods of heat treating, metal cutting, machining processes, nontraditional processing methods and joining processes. 3 lec.</td>
</tr>
<tr>
<td>• <strong>20INDS411. Quality Control and Reliability.</strong> 3 cr. Total Quality Management, statistical basis for quality control. Control charts, process control, process capability, reliability analysis. 3 lec.</td>
</tr>
<tr>
<td>• <strong>20INDS438. Ergonomics.</strong> 3 cr. Basic ergonomic principles needed to recognize and evaluate workplace ergonomic problems; physiological, anthropometric, environmental factors and performance. 3 lec.</td>
</tr>
<tr>
<td>• <strong>20INDS440. Work Measurement.</strong> 3 cr. Facilities organization and work place design; utilization of human resources, productivity improvement, incentives. 3 lec. Prereq.: 20INDS411.</td>
</tr>
<tr>
<td>• <strong>20Mine451. Engineering Economy.</strong> 3 cr. Principles for making decisions among competing engineering alternatives on the basis of their return on investment. 3 lec.</td>
</tr>
<tr>
<td>Course Code</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>20INDS452</td>
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<td>20INDS453</td>
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<tr>
<td>20MINE586</td>
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<tr>
<td>20MINE587</td>
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## Dual Level Courses (Open to Undergraduate and Graduate Students)

- **20INDS520. Occupational Safety.** 3 cr. An engineering approach to the control of loss exposures in business and industry. Course considers risks to employees, facilities, production, market position, and the environment. 3 lec.

- **20INDS613. Design of Experiments.** 3 cr. The use of experiment design and analysis in problem solving; discussion of methods of experimental design and analysis so that the statistical analysis will yield the maximum useful information. 3 lec.

- **20MINE621. System Safety I.** 3 cr. Introduction to fundamental concepts of risk management. Application of engineering analysis techniques to identify system hazards and reduce risk. Safety engineering. Techniques include preliminary hazard analysis (PHA), Barrier Analysis, failure mode and effects analysis (FMEA), Hazard and Operability (HAZOP) Studies, management oversight and risk tree (MORT) and job safety analysis (JSA). 3 lec.

- **20MINE622. System Safety II.** 3 cr. Concept of risk during life cycle and its relationship to comprehensive loss prevention and control. Techniques include Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Sneak Circuit Analysis and Cause-Consequence Analysis. Introduction to software system safety. 3 lec.

- **20INDS624. Human Factors Analysis.** 3 cr. Analysis of work and individual factors in organizations with the objective to create and maintain a healthy/safe and productive workplace. Discussion of theories of human factors, micro-and macro-ergonomics, industrial psychology, work analysis and stress, and psychosocial research to gain an understanding for a holistic evaluation of work and individual factors as a prerequisite for a safe, healthy and productive work. 3 lec. Prereq.: 20INDS438 or permission of instructor.

- **20INDS625. Human Factors Design.** 3 cr. Discussion of human factors theories on work design to gain a global understanding of how to achieve a balance among the different elements in the work system and balance between work and human abilities & needs to ensure that the health and safety of workers are taken into account and that human productivity is maximized in the organization. 3 lec. Prereq.: 20INDS438 or permission of instructor.

- **20MINE636. Introduction to Robotics.** 3 cr. Introduction to industrial robots, components, programming, and applications. A feasibility study, for the use of industrial robots, is conducted as a project. 3 lec. Prereq.: Senior standing.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20MINE638</td>
<td>Robot Design</td>
<td>3 cr.</td>
<td>Kinematics and dynamics of robots. Robot design process starting from specifications. 3 lec.</td>
</tr>
<tr>
<td>20MINE639</td>
<td>Robot Vision</td>
<td>3 cr.</td>
<td>Introduction to robot vision, intelligent robotics, mathematics, programming and control. Machine intelligence, expert industrial systems, sensors and vision, applications to flexible manufacturing system design. 3 lec.</td>
</tr>
<tr>
<td>20MINE640</td>
<td>Management of Professionals</td>
<td>3 cr.</td>
<td>Introduction to the principles and procedures of management for professionals; role of administration in engineering, health care, and other professional areas. 3 lec. Prereq.: Senior standing.</td>
</tr>
<tr>
<td>20INDS641</td>
<td>Advanced Manufacturing Processes</td>
<td>3 cr.</td>
<td>Advanced topics in machining including analysis and modeling of stress, strain, cutting forces, temperature, surface finish, tool wear, chatter, and economics of machining processes. Recent trends in manufacturing processes including high speed machining, coated tools and superabrasive (CBN) Grinding 3 lec.</td>
</tr>
<tr>
<td>20INDS650</td>
<td>Intelligent Systems Theory</td>
<td>3 cr.</td>
<td>Introduction to intelligent systems such as expert systems, neural networks, adaptive and learning systems with applications to manufacturing and material handling. 3 lec. Prereq.: Senior standing.</td>
</tr>
<tr>
<td>20INDS653</td>
<td>Industrial Environment Engineering/ Evaluation and Control</td>
<td>3 cr.</td>
<td>Evaluation and control of individual environment-noise, illumination, heat, air, vibration, radiation and ventilation. 3 lec. Prereq.: Senior standing.</td>
</tr>
<tr>
<td>20INDS655</td>
<td>Interface Design</td>
<td>3 cr.</td>
<td>Evaluation and design of human-machine interfaces, controls and displays, human-computer interfaces, design guidelines, interface survey, usability analysis and testing, interface consistency. 3 lec. Prereq.: Senior standing.</td>
</tr>
<tr>
<td>20INDS656</td>
<td>Human Factors in Product Design</td>
<td>3 cr.</td>
<td>Topics include: an overview of human factors and the design process; product planning; design activities; human factors research and testing; displays; information design; controls and control arrangements; keyboards and input devices; theory and design strategies for user interface software; physiological, biomechanical, and anthropometric considerations; data and guidelines for product configuration, behavioral and legal aspects of product safety; designing safe products. 3 lec. Prereq.: Senior standing.</td>
</tr>
<tr>
<td>20MECH685</td>
<td>Introduction to Biomechanics</td>
<td>3 cr.</td>
<td>Basic concepts and methods involved in the applications of mechanical engineering principles in the medical and life sciences. 3 lec.</td>
</tr>
<tr>
<td>20MECH686</td>
<td>Tissue Biomechanics</td>
<td>3 cr.</td>
<td>Examination of properties and mechanical behavior of the structures, soft tissue, and organs of biosystems. 3 lec.</td>
</tr>
</tbody>
</table>
• 20MECH687. Human Body Dynamics. 3 cr. Introduction to human body modeling. Bones; soft tissue; internal organs; experimental and analytical results; applications in injury analysis, rehabilitative therapy, and sports mechanics. 3 lec.

• 20INDS697. Seminar in Industrial and Manufacturing Engineering. 1 cr. Selected topics in the field of Industrial and manufacturing Engineering. 1 lec.
I. GENERAL CRITERIA FOR BASIC LEVEL PROGRAMS

It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

Criterion 1. Students

The quality and performance of the students and graduates are important considerations in the evaluation of an engineering program. The institution must evaluate, advise, and monitor students to determine its success in meeting program objectives. The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2. Program Educational Objectives

Each engineering program for which an institution seeks accreditation or reaccreditation must have in place:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
(c) a curriculum and processes that ensure the achievement of these objectives
(d) a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.

**Criterion 3. Program Outcomes and Assessment**

Engineering programs must demonstrate that their graduates have:

(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
(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 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.

Each program must have an assessment process with documented results. Evidence must be given *2001-2002 Criteria for Accrediting Engineering Programs* 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. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content.
examinations; alumni surveys that document professional accomplishments and career
development activities; employer surveys; and placement data of graduates.

**Criterion 4. Professional Component**

The professional component requirements specify subject areas appropriate to
engineering but do not prescribe specific courses. The engineering faculty must assure
that the program curriculum devotes adequate attention and time to each component,
consistent with the objectives of the program and institution. Students must be prepared
for engineering practice through the curriculum culminating in a major design
experience based on the knowledge and skills acquired in earlier course work and
incorporating engineering standards and realistic constraints that include most of the
following considerations: economic; environmental; sustainability; manufacturability;
ethical; health and safety; social; and political. The professional component must
include:

(a) one year of a combination of college level mathematics and basic sciences (some
    with experimental experience) appropriate to the discipline
(b) one and one-half years of engineering topics, consisting of engineering sciences and
    engineering design appropriate to the student’s field of study
(c) a general education component that complements the technical content of the
    curriculum and is consistent with the program and institution objectives.

**Criterion 5. Faculty**

The faculty is the heart of any educational program. The faculty must be of sufficient
number; and must have the competencies to cover all of the curricular areas of the
program. There must be sufficient faculty to accommodate adequate levels of student-
faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students. The faculty must have sufficient qualifications and must ensure the proper guidance of the program and its evaluation and development. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and registration as Professional Engineers.

**Criterion 6. Facilities**

Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the institution.

*2001-2002 Criteria for Accrediting Engineering Programs*
Criterion 7. Institutional Support and Financial Resources

Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 8. Program Criteria

Each program must satisfy applicable Program Criteria (if any). Program Criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Requirements stipulated in the Program Criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of Program Criteria, then that program must satisfy each set of Program Criteria; however, overlapping requirements need to be satisfied only once.
MIRA LALOVIC is a doctoral student of industrial and manufacturing engineering at the University of Cincinnati. Her research is centered around applied statistics, quality control, process control, and management. Her recent work and publications have focused on the use of Six Sigma in service industries such as academia. She is also the only non-faculty member of the ABET assessment team for the College of Engineering at the University of Cincinnati.

Dr. RICHARD L. SHELL is a professor of industrial and manufacturing engineering at the University of Cincinnati. He is responsible for teaching and research in industrial and safety engineering. His current affiliations include the Institute of Industrial Engineers, the Society of Manufacturing Engineers, the Human Factors Society, the International Reading Association, and the American Society for Engineering Education.

Dr. L.E. “ROY” ECKART is Associate Dean of Academic and Administrative Affairs in the College of Engineering at the University of Cincinnati. His field of specialization and areas of interest are radiological environmental assessment and human health risk assessment. He is responsible for teaching and research in health physics and radiological engineering, and supervision of sponsored research at DOE facilities.
Dr. RONALD HUSTON is Mechanical Engineering Program Director at the University of Cincinnati. His research interests include multibody dynamics, biomechanics, crash victim simulation, sports mechanics, cable dynamics, finite element methods, contact stresses, and gear and transmission dynamics. He is a member of the American Society for Mechanical Engineers, the Human Factors Society, the Institution of Diagnostic Engineers (Founding Fellow), the International Society of Biomechanics, the Society for Industrial and Applied Mathematics, the Tensor Society of Great Britain, the Ohio Academy of Sciences, NSPE, IIE, and many others.

Dr. ALI A. HOUSHMAND is the Dean of the Richard C. Goodwin College of Evening and Professional Studies, the Associate Provost for Academic Affairs, and a professor of engineering management at Drexel University in Philadelphia, Pennsylvania. His research and teaching interests center around applied statistics, quality control, design, and management. He is a member of ASQC, IIE, ASEE, and INFORMS.