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The University 'Manufacturing' System: ISO 9000 and Accreditation Issues*

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The customers of the university should have confidence that their requirements for quality are met on a continuous basis, and that the students will have the required knowledge when they graduate. In this paper, the university is viewed as a manufacturing system, with defined customers and suppliers. The objective is to show that 'quality' must and can be assured more clearly and convincingly to the general public with reference to the ISO 9000 standards.

INTRODUCTION

TODAY, customers expect quality in all aspects of their lives. Companies are re-engineering to assure the customers of high quality of their products and services. In light of this fact, education is no exception. The customer wants to be assured that educational institutions provide quality service. To assure that their students have adequate knowledge in the area of expertise, engineering faculties in Canada undergo the accreditation process by the Canadian Engineering Accreditation Board (CEAB). This provides a platform for standardizing degree programs, such as mechanical engineering, across Canada. However, increasing globalization yields a need to assure customers, not only locally, but internationally, of the quality of educational services being provided [1].

Such standardization efforts in the industrial sector have led to the introduction of ISO 9000 International Standards. These generic standards were derived mainly by professionals and managers involved in manufacturing. The standards provide a framework for emphasizing the organization's commitment to quality, as well as making quality efforts visible to customers. The impact of the standards world-wide has been so extensive, that it is now virtually impossible to bid for international contracts if a company is not ISO 9000 registered. Considering the fact that ISO 9000 standards are generic in nature, they should be equally applicable to service organizations, such as software companies, health care and education. The application to services, however, requires an interpretation of the standard, as well as the definition of terminology, within the context of manufacturing.

Although educational institutions are considered as service organizations, this paper views the university as a production system (Fig. 1). Final customers of the university are organizations the graduated students work for. The customers specify quality characteristics, such as employability, ability of students to solve engineering problems and ability to upgrade their knowledge. Industry specifications are 'market driven', and CEAB specifies engineering knowledge fundamentals. These specifications are then translated into engineering programs, and detailed in courses students are required to take.

The university receives its students from high schools and colleges. After passing the admission, students go through four years of education, by taking a number of courses each year. Their knowledge is induced by the faculty (professors, assistants and technicians), with teaching and learning processes supported by university administration. At the end of each year, they have to meet certain requirements in order to pass to the next year, or to graduate. The customers (industry, government and society) should be assured that their requirements for quality are met on a continuous basis, and that the students will have the required knowledge when they graduate.

Universities all over the world state that this is exactly what they do. For example, in its mission statement, The University of Manitoba seeks 'to provide the highest possible quality of undergraduate and graduate university teaching' and 'to conduct original scholarship and basic and applied research . . . of highest quality as judged by international standards'. The objective of this paper is to show that 'quality' must and can be assured more clearly and convincingly to the general public with reference to the ISO 9001 standard.

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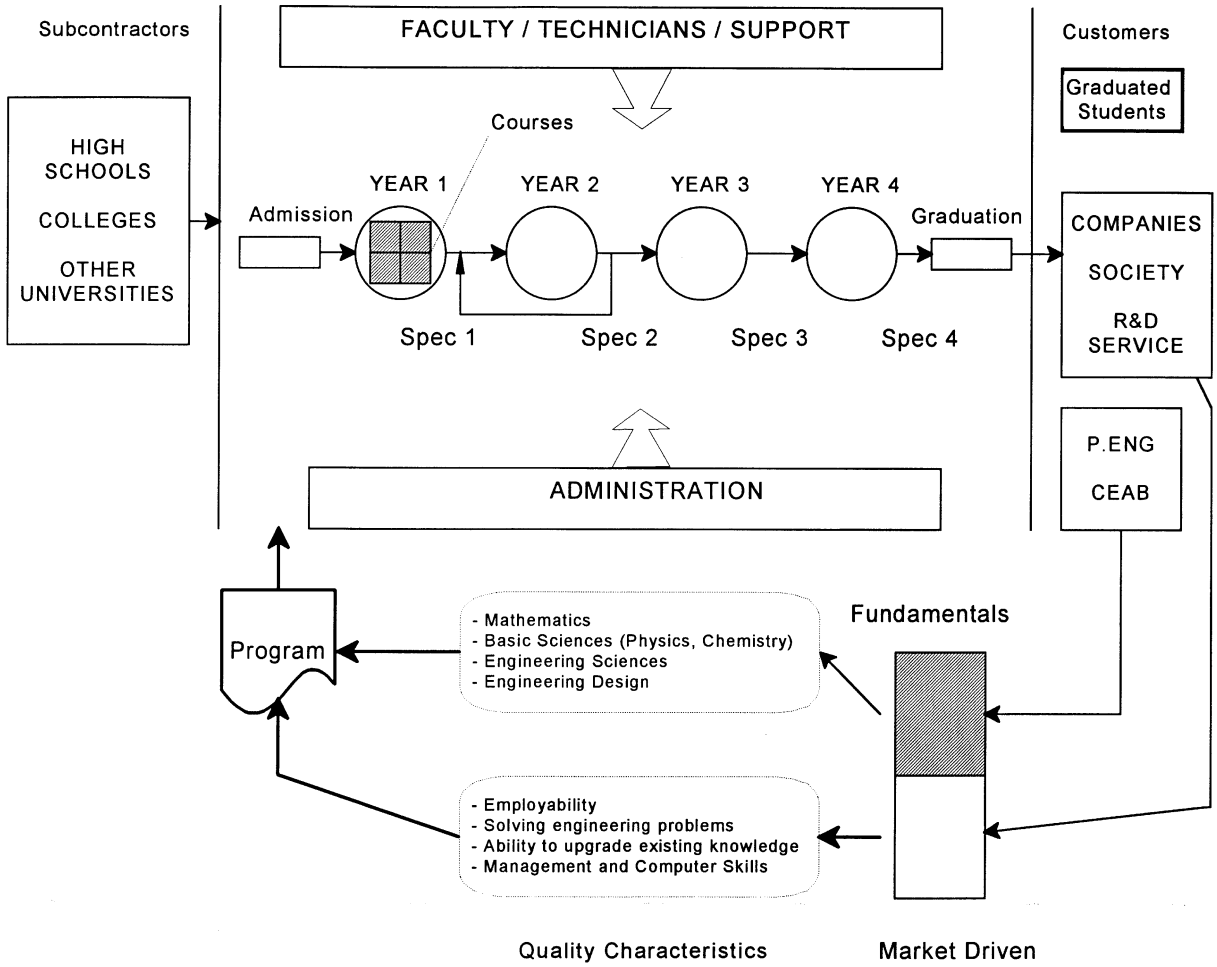

Fig. 1. The University Manufacturing System.

THE UNIVERSITY MANUFACTURING SYSTEM

In order to understand the University Manufacturing System (UMS), we need to understand its products: student knowledge, courses and research output, as well as its basic processes: learning, teaching and research. The following sections will address these in detail, as well as discuss a few quality characteristics of the products.

Student knowledge

A student comes into the first year of university studies with the knowledge of basic arts and sciences acquired in the high school. Thus, this knowledge is raw material the university receives from its subcontractors: high-schools and/or colleges [2, 3]. The university performs incoming inspection of the student's knowledge, by accepting only the students who received high school grades which meet the university entrance requirements, and/or students who passed required entrance exams (Fig. 1).

The curriculum usually consists of four years of study. Students are required to attend and pass a certain number of courses each year. For example, in mechanical engineering at the University of Manitoba, a student has to pass twelve courses each year. As a student attends courses of the first through the fourth year, he accumulates the knowledge in a process analogous to the part assembly in manufacturing. The final product (e.g. knowledge of a mechanical engineer) consists of the knowledge of matter taught in the courses: (e.g. thermodynamics, strength of materials, design, etc.). Thus, a part in manufacturing is analogous to the knowledge of a student acquired in a specific course.

Student's achievement (courses taken and grades) is inspected at the end of each year, in order to (dis)allow the student to proceed to the consecutive year. This in-process inspection is followed by the graduation, or final inspection to confirm that the student has met all the requirements. After graduation, a student is employed by industry, government, the private sector, self-employment or society in general. These companies and society are the final customers of student's knowledge. They are the market the university provides its 'product' to.

The customers set the requirements for the product. For example, industry may want mechanical engineering graduates to possess knowledge on time management, quality control and automation, while the government wants them to be familiar with workplace health and safety regulations and quality standards. The knowledge of a graduate must also contain certain implied theoretical principles and fundamentals. For example, a mechanical engineer must be familiar with thermodynamics principles, and be able to solve conceptual problems in this area. These fundamentals, for engineering arts and sciences, are set by the Association of Professional Engineers (P.Eng) and the CEAB (Fig. 1).

On the basis of student knowledge requirements, the university designs its programs and courses.

Courses

The university, or faculties and departments within, design the programs, with design specifications which include a list of courses offered and brief descriptions of course content. These are usually given in the University's General Calendar. Based on the course content specifications, professors design and plan how the courses are to be executed. They plan methods of teaching (using computers, or classical 'chalk and board' method), the matter to be included in the course, lectures and/or laboratory experiments. The Teaching Process plan is provided in the course outline, handed out to the students at the beginning of the course. The document describes the order of lectures, the topics covered in each lecture, and how he/she plans to perform the lectures. It also prescribes when the exams, tests, assignments and/or quizzes are to be performed, what characteristics of the student knowledge are to be inspected and how. At this point of time onwards, the real teaching and learning process takes place.

For each topic planned in the course outline, the teacher performs lectures. With each lecture, the teacher is creating new dimensions to the student knowledge. These dimensions must be within the specification limits, set in the course outline. For example, if a student received more than 60% on a test, he/she will pass. After students have gone through the course and passed the final exam, they leave to attend another course. Knowledge gained from the course adds to the knowledge acquired from the courses previously passed. Thus, it is important to recognize that each professor is an 'internal customer' to the other one.

One fact has to be considered at this time, however. There is no tangible knowledge gained if there are no students attending a course, even though a teacher may theoretically teach in front of an empty auditorium. There is no 'product' without the 'raw material'. Without students the course has no meaning. It is a simple drawing of what a teacher would like to teach. Therefore, the mechanical engineering program is only a set of design specifications. The course content is only a process plan.

Materials, skills and expertise required to develop and deliver courses (the 'Learning Opportunity') constitute the technology which is being used to produce knowledge. Mechanical engineering departments from different universities use different technologies to manufacture the same 'product': the mechanical engineer. There are different ways to make a car. You can use different machines, different tools, and still come up with similar cars.

The learning opportunity is created by the university as a product for its own purposes. The university is analogous to a manufacturing organization that produces the machines it will use for manufacture of their primary product. For example, one of the largest producers of industrial robots in Europe is a German automotive company. However, the company does not sell its robots: they are used to make their own cars.

Research output

The university also performs research activities upgrading the existing knowledge. The outcome of these activities (new technologies, tools, published papers) is considered to be one of the final products, as well. The customers are the companies, society and governmental agencies encountering problems for which solutions are not already available. Raw material is the existing knowledge in the area of research, supplied by libraries, fellow researchers, interested industries. A research process, lead by one or more professors, involves graduate students, technicians and support staff. The process encompasses data acquisition, conceptualization, development and final inspection. The results are supplied to customers.

Teaching, learning and researching interrelationships

The products are created using certain processes. Student knowledge is gained by learning, courses are taught, and new knowledge is achieved by researching. In a university environment, there is an interrelationship among these processes, that has an impact on the quality of the products. The quality of teaching/learning/researching is inspected against specifications. The teacher has to meet the specifications set in the course outline, and is evaluated by the students and their peers. Each student has to meet the specifications the teacher has set in the outline. A Professor's research output is evaluated by his/her peers.

Learning is performed by students. The objective of teaching is to lead the students through the course and provide the opportunity for learning. As a part of this process, a professor teaches certain prescribed material, and discusses the relevant issues in class. A student is expected to understand the material, and by self-learning, enhance knowledge to meet specifications.

In discussion of quality issues in education, there is a need to identify the difference between teaching and learning. In teaching, if a professor does not cover all the material, there is a discrepancy with respect to specifications set in course outline.

This leads to the following. Some students might not gain knowledge in the area the professor has taught, while others, due to self-learning, might. In spite of the professor not performing according to specifications, students may conform to the requirements. On the other hand, if the professor meets all the requirements, a student still may not learn it all. These relationships are best described in Fig. 2.

At this point, a distinction between manufacturing and education becomes evident. In manufacturing, a part never talks back to the operator. In education, the feedback from students assists the professor in fine-tuning the learning opportunity. In this sense, the students can be treated as customers. However, we treat them as 'passive customers', since they cannot change the customer specifications, at least not until they graduate.

Quality characteristics

The quality of a university's products is measurable. Each product encompasses certain quality characteristics, which can be measured against specifications. The following are examples of the three products characteristics in the engineering faculty.

Student knowledge: employability of graduated students and ability of graduates to successfully solve engineering problems, measured by:

- the percentage of recent graduates employed
- the average starting salary
- percentage of graduates registered as professional engineers
- number of awards received by students in engineering competitions.

Courses: attractiveness to students and availability of resources, measured by:

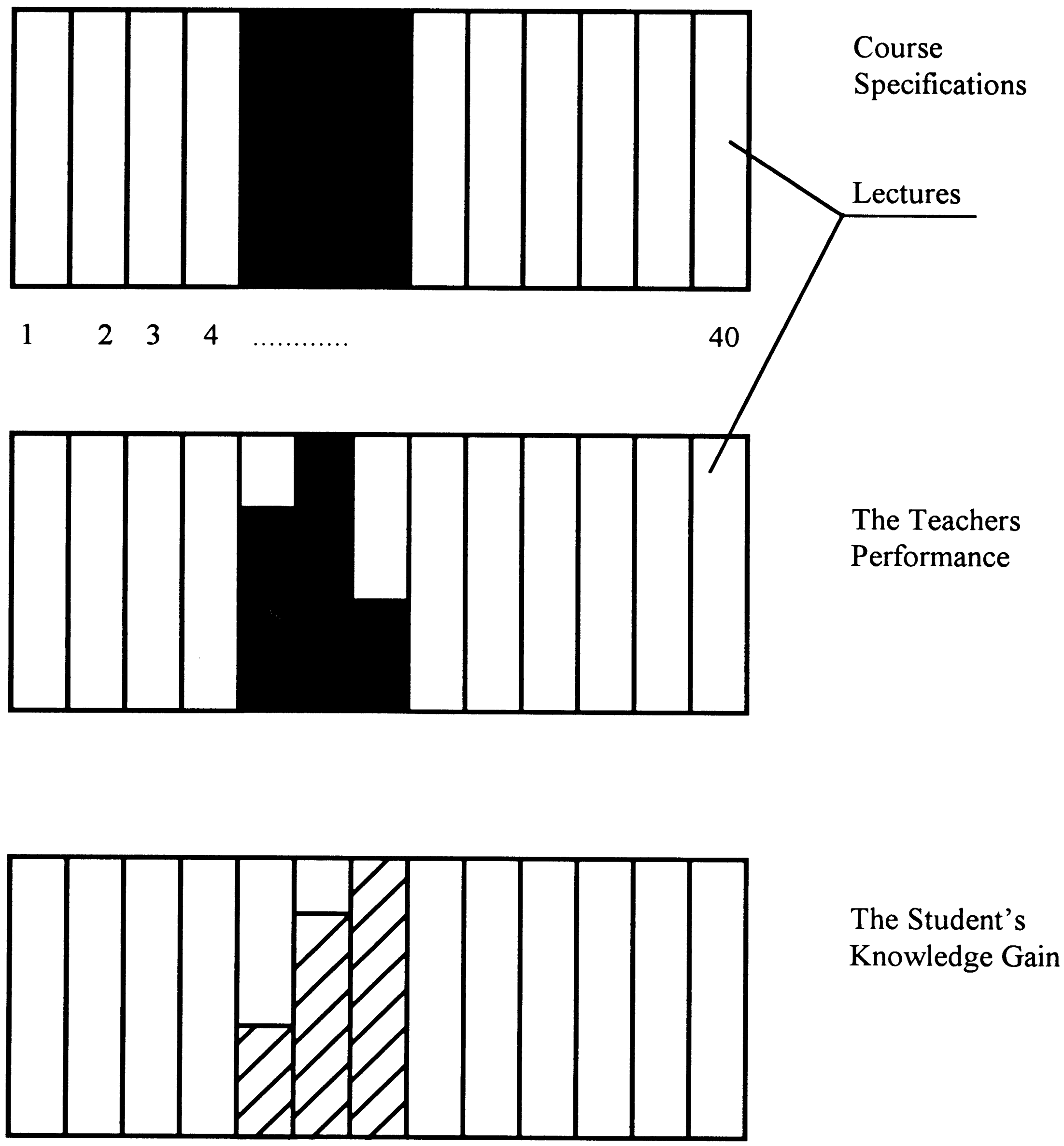

Fig. 2. Teaching vs. learning.

- student evaluation
- failure rate
- professor to student ratio
- percentage of faculty registered as professionals engineers.

Research output: contributions to existing theories and/or practices, reputation and success:

- number of papers published in refereed journals and/or conferences
- number of patents
- reputation rank by academics and practicing engineers
- research funds received from the government, industry and society.

Quality characteristics are considered to be crucial for measuring 'quality'. Universities should define what the critical quality characteristics are in their quality policy statement.

ISO 9000 AND CEAB

How will ISO 9000 help universities? ISO 9000 is focused on providing confidence to customers and university management that the requirements for quality will be continuously met. In terms of customers, these requirements may be collected and documented through surveys of interested industries, governmental agencies, society, graduates and students. In terms of university management, requirements for quality are expressed in the quality policy, or university mission. On the other hand, ISO 9000 *will not* ensure that the university produces students and/or research at the world class level, nor will it facilitate employee empowerment and total quality management. Figures 3 and 4 provide an insight to what a university can expect from the implementation of a quality assurance system that complies with the ISO 9001 standard, and what not, respectively. A representative example to illustrate the impact of ISO 9000 on the university follows. The example focuses on some of the customer concerns (with relevant section numbers of ISO 9001–94).

- *Does the professor know the quality policy of the university?* ISO 9000 will ensure that the quality policy is defined, implemented and understood at all levels of the university (4.1.1).
- *Is the equipment not working?* ISO 9000 provides means of proper documentation of nonconformancies (4.13), such as the overhead projector

WHAT ISO 9000 WILL PROVIDE
Confidence to: ◆ the students, industry, government and society ◆ the university and faculty management that the requirements for quality are continuously met
An effective marketing tool
Unambiguous definition of the responsibility and authority of all persons involved in teaching/learning/research, including: professors, teaching assistants, students, administrative staff, technicians and support staff
For the adequate determination of the customer requirements for quality
For the continuous information-monitoring and feedback system
Adequate documentation of program/course design activities and output
Adequate and unambiguous documentation of the student entrance requirements, hiring new staff and material
Adequate evaluation of high-schools, colleges and universities students come from
Streamline and make documentation clearer
Identification and traceability of all records, student/course/research progress
Ensure that there are procedures available for control of the teaching/learning/research processes, including: reliability of laboratory, computer, library equipment, student counseling, as well as continuous feedback to the student
For the adequate documenting procedures for conducting and reporting the results of all tests, assessments, exams, quizzes, including graduation
Adequate documentation of professor advancements, merit awards and/or nonconformance
Adequate control of student/staff/research failure
Internal Quality Audits
Adequate use of statistical techniques

Fig. 3. ISO 9000 benefits.

WHAT ISO 9000 WILL NOT PROVIDE
Assurance that the university produces students and/or research at the world class level
Costs cutting tool
Total Quality University
Employee participation and empowerment
Benchmarking
More documentation

Fig. 4. ISO 9000 will not do this.

MANUFACTURING	UNIVERSITY: Faculty of Engineering
Product	(a) Students knowledge, experience & skills (b) Courses (c) Research Output
Customers	(a) Industry & Society (b) P.Eng & CEAB (c) Graduated Students
Supplier	The University
Subcontractors	High-Schools Colleges
Executive Management	(1)The dean, & department heads (2) Boards, councils, committees
Design Plan	Industrial Engineering Program, Mechanical Engineering Program, M.Sc (IE) program, etc.
Designer	Professor
Process Plan	Course outline
Raw Material	Students knowledge of basic sciences before entering the faculty
Value Adding to Material	Value adding to students knowledge
Manufacturing Process	Teaching/Learning/Research process
Lead Time	4 years
Part	Students knowledge accumulated in a course
Operation/Tool	Lecture
Machine/Technology	"Learning Opportunity"
Operator	Teacher, Teaching Assistant
Part Specification	Course Specification in General Calendar
Inspection	Exams, Tests, Assignments

Fig. 5. Summary of analogies.

not working, as well as adequate corrective and preventive actions (4.14).

- *Are the courses regularly updated on the current scientific events?* The professor's training and updating on the current theories/practices is ensured (4.18).
- *What if the professor decides to change a course without customer's reference?* Course design

TERM	EXPLANATION
Quality Policy	The overall quality intentions and direction of a faculty as regards quality, as formally expressed by the dean.
Quality Management	The aspect of the overall faculty management that determines and implements the quality policy.
Quality Assurance	All those planned and systematic actions necessary to provide adequate confidence to the customers & faculty management that the product will satisfy given requirements for quality.
Quality Control	The operational techniques and activities that are used to fulfill requirements for quality at the faculty level.
Quality System	Organizational structure, procedures, processes, responsibilities and resources for implementing quality management (ISO 8402-94).
Management Review	Management review includes: (1) Internal Quality Audits (2) An overview & analysis of quality policy (3) The analysis of customers requirements and their relationship to the policy/objectives
Quality System Review	A formal evaluation by the dean and department heads of the status and adequacy of the quality system in relation to quality policy and new objectives resulting from changing circumstances.
Design Review	A formal evaluation by the department heads of the course design to evaluate course requirements and the capability of the courses to meet these requirements.
Inspection	That aspect of the faculty-wide quality control that measures, examines and tests one or more characteristic of the service and compares these with specified requirements to determine conformity.
Nonconformity	The nonfullfilment of specified requirements (ISO 8402-94) Examples: student failure, course failure, research project failure
Defect	The absence of one or more quality characteristics from intended specifications.

Fig. 6. Terminology.

changes must be reported and documented (4.4). Obsolete documents must be destroyed or disposed of (4.5).

- *Is a student given a precise plan of what he/she is supposed to learn, when the exams are going to be and what will be tested on the exams and tests ?* ISO 9000 ensures that there are procedures in place for administration of the course, including a standardized course outline, and ensures that this outline is handed out to and understood by the students at the beginning of each course (4.4 and 4.9)
- *What if the professor is not following the course outline?* The student is entitled to raise a nonconformance report to the department. If the department does not perform corrective and preventive actions upon this request, ISO 9000 registration will not be granted, or, if already granted, will not be renewed (4.13).
- *How can a student be assured that his/her assignment will not be lost?* ISO 9000 (4.7 and 4.8) prescribes documented procedures for the identification and traceability of a document supplied by the student, as well as proper care to ensure that it is not lost or damaged.
- *How is the customer assured that his/her specifications are known by the University?* Section 4.3 contract review ensures that procedures are in

	ISO 9001-94 (Interpretation for the Engineering Faculty)																				
CEAB	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12	4.13	4.14	4.15	4.16	4.17	4.18	4.19	4.20	NA
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Fig. 7. CEAB vs. ISO 9000 cross-references.

place for the precise definition of what is expected from the university and for regular review of these requirements.

ISO 9000 interpretation

The University Manufacturing System (UMS) is shown in Fig. 1. Interested readers can interpret the standards themselves, using the UMS concept with a summary of analogies and terminology presented in Figs 5 and 6, respectively.

CEAB

Engineering faculties in Canada have already encountered accreditation of their programs. The Canadian Engineering Accreditation Board (CEAB) evaluates undergraduate degree programs offered at Canadian universities and accredits those which meet minimum standards. The CEAB publishes yearly revised guidelines for accreditation in forms of questionnaires. Questionnaires are filled in by the interested engineering department, and sent to the CEAB. This is followed by the site visit, where the CEAB team examines the curriculum, laboratory, computer and library facilities, and performs interviews with the faculty, students and staff. A detailed illustration of the CEAB accreditation of an engineering program is provided in Ref. 1. The author has stated a number of problems encountered with the CEAB registration. Among others, CEAB does not provide guidelines for the specific course content, and site visits may be biased towards a particular area. ISO 9000, as a minimum standard, is proposed for engineering accreditation.

ISO 9000 VS. CEAB

In this section, a few general observations are made regarding ISO 9000 and CEAB, followed by a comparison of their elements. It can be concluded that:

- Both ISO 9000 and CEAB are designed to evaluate, verify and to make results visible to the public.
- CEAB accreditation is specific for an engineering faculty, while the registration to ISO 9001 is generic and open to any faculty and/or department.
- CEAB evaluation consists of response to a questionnaire, followed by a visit of qualified professional engineers. On the other hand, ISO 9001 Quality System is described in an international standard that guides the documentation and implementation of the system. Compliance with the Standard is assessed by accredited and trained auditors.
- The object of CEAB accreditation is a faculty's undergraduate program. ISO 9001 registration is restricted to quality assurance activities, and encompasses all programs within the department (both undergraduate and graduate).

To provide a comprehensive comparison, the elements of CEAB questionnaires were cross-referenced versus the twenty elements of the ISO 9001-94 (Fig. 7). The comparison illustrates that the CEAB questionnaire provides information on the persons responsible for the program, program/course design, facilities available for the teaching/learning/research process and faculty (professors). It provides the information on the *resources* existing for conducting the program, and the manner the program/courses are *planned* to be executed (design input). However, the information on how the courses are actually *executed* is not available. In general CEAB places little focus on explicit quality and quality assurance. The question: 'How does the faculty of engineering assure their various interested and involved parties of the adequate quality of services rendered?' is neither posed nor indirectly answered. ISO 9001, however, addresses this valid question.

THE PATH TO ISO 9000 THROUGH CEAB

An engineering faculty that is accredited by CEAB complies with most of the requirements of the ISO 9001 standard. Preparing the documentation that addresses the twenty requirements of ISO 9001 should not cause major problems to the faculty and its individual departments and members. The documentation already developed for CEAB accreditation purposes can be used for part of the required ISO 9000 documentation.

However, a comprehensive Quality Manual for the faculty, covering the twenty elements of ISO 9001–94 should be prepared. A Departmental Quality Procedures Manual, consistent with the Faculty Quality Manual, should be drafted. In both manuals, it is possible to refer to the already existing quality related procedures and instructions, which will greatly limit the scope of this documentation effort.

CONCLUSION

The University Manufacturing System (UMS) has been presented. The relevance and need of ISO 9000 in education has been discussed, followed by the illustration of the path to ISO 9000 through CEAB accreditation for an engineering faculty. It is anticipated that after ISO 9001 registration, a university will have an effective quality system that will assist in creating a total quality organization.

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