SETTING OBJECTIVES AND STRATEGIES FOR ENGINEERING AND ENGINEERING TECHNOLOGY PROGRAMS

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A former deputy minister of education recently said: "The Philippine educational system is irrelevant and elitist, is not attuned to the needs of the times, and is oriented more to the welfare of the rich." (*Bulletin Today*, February 16, 1980)

An evaluation of our engineering education programs in the Philippines shows that utilization of graduates does not conform to the objectives of college programs or to the definitions established by educators. We often hear people from the industry saying that "real" engineering is not that which is practiced in the classroom with fully specified problems and specific answers obtainable by analytical methods. It is more likely to involve ambiguity and uncertainty. They also say that the most important decisions must often be made without the assistance of higher mathematics. Furthermore, it is observed that there is considerable confusion and misunderstanding in the industry and among educators concerning the rôles to be played by engineering or engineering technology programs and by their respective graduates. This situation results in the employment of engineers who are performing as technicians or technologists.

If we are going to have a quality control of the processes and outcomes of an education program, the evaluation text can be summarized into four basic questions:

1. Why? — What needs can you cite that justify the existence of this educational program?
2. What? — What are your objectives in the program? That is, what objectives will the program accomplish to meet the need under *Why?*
3. How? — How will you have the program function to meet its objectives?
4. How will you know? — What kinds of information should be gathered so that you know if the *how* is meeting the *what* for the *why?*

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Although the topic given to me for discussion is on the What and How of the evaluation process, it has to be recognized that the How (strategies) is identified for the purpose of meeting the What (objectives) for the Why (need).

The Need

The success of a program is dependent upon the need. Just like in the development of a technology, most successfully innovations come about as a result of demand or need rather than from supply of results of scientific researches.

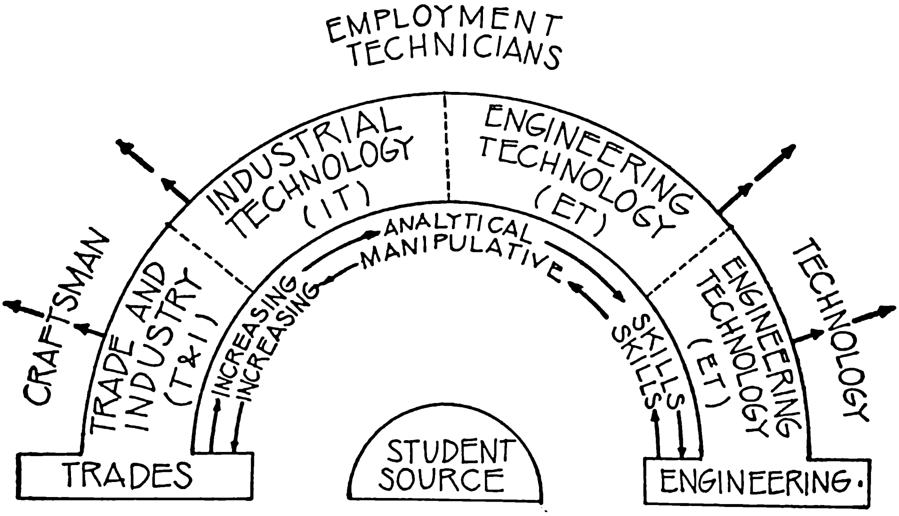
The observations from the industry which were previously mentioned are indications that our engineering education programs, as well as their respective objectives, are not satisfying their needs. In the light of this situation, the following questions are then worth consideration to define the needs that will justify the existence of an educational program:

1. What engineering and engineering technology education programs are needed?
2. What are the roles to be played by these programs and by their respective graduates in industry as well as in government?

These questions can be properly answered if there is more interaction between educational institutions and the industry. The objectives of the educational programs can then be well defined and programs can be properly structured to meet the needs. Only then can we prevent the lack of integration between the objectives of enginering education and the practice of engineering as experienced by graduates.

For example, California Community Colleges and City College of San Francisco developed the following spectrum of occupational-technical education programs ranging from trades (including apprenticeship training) at one end, to the professional engineering at the other. The figure is not a flow diagram; it illustrates the interface of the educational program and the rigor and content of the curriculum in terms of "increasing analytical skills" (mathematics and science) and "increasing manipulative skills". It should be noted that the program categories overlap rather than form a series of isolated entities.

Industrial technology is considered to designate those curricula that prepare a person for employment as an industrial technician in production, service, construction, or related fields. These curricula are distinguished by a greater amount of mathematical and technical subject matter than is found in the traditional trade and industry curricula and generally provide greater opportunities for career advancement. Entry level employment, however, may be quite similar. These industrial technology programs are primarily occupationally oriented and do not represent the recommended lower division course work for the bachelor of industrial technology (B.I.T.).



EDUCATIONAL / EMPLOYMENT SPECTRUM
OF TECHNICAL EDUCATION

Engineering technology comprises those two-year curricula that prepare a person for employment as an engineering technician in direct support of an engineer, as well as those curricula that serve as lower division preparation for matriculation to a four-year baccalaureate degree program, normally in engineering technology. The graduate may also select other kinds of advanced training. The program aim at preparing students for immediate usefulness in technical employment. They are technological in nature with instructions offered in the broad area of technical education at levels between engineering and vocational education — industrial technology.

Program Objectives

The program objectives define in specific terms what are expected to be accomplished in order to meet the identified needs. The attainment of these objectives and the satisfaction of the needs reflect the adequacy of the objectives. If the needs are not met, either the objectives are not adequate or there is lack of integration between objectives and needs.

Let us consider, for example, a program for engineering technology to meet the need of the industry for engineering technicians. We may agree to have the following objectives:

Overall Objective: To prepare a person for employment as an engineering technician in direct support of an engineer.

Specific Objectives:

1. To make the student proficient in the analytical use of mathematics, including algebra, geometry, trigonometry and possibly

introduction to analytic geometry and calculus, with emphasis on application and problem-solving and minimal treatment of derivations and theory.

2. To give the student an understanding and the ability to apply the concepts of physics, chemistry, and other physical sciences appropriate to the technical discipline and commensurate with the level of computational skills defined in objective 1.
3. To make the student proficient in analytical and manipulative skills requisite to the broad support requirements of the engineer and other technical personnel in related technical disciplines, such as: data acquisition and analysis; design; testing, evaluation and troubleshooting. He should be capable of performing these activities with minimal supervision.
4. To provide the student with the necessary training in order that he will be able to prepare, interpret and transmit technical information acquired by and for the engineer and other technical and management personnel utilizing the oral, written, computer, and graphic language of the discipline.
5. To train the student for other skills required to enable him to work and communicate and interact with both subordinates and superiors. This may require knowledge about the principles of practical economics, environmental requirements, and the safety aspects pertinent to the engineering discipline.
6. To develop students in their formative years into continuous learners.

It will be noted that the above specific objectives define the requirements of the need. Specifically, the required computational skills, understanding of the physical sciences, technical skills, communication skills and related technical skills of an engineering technician are defined in relation to the need

Strategies

How will the program function to meet the defined objectives? This question leads to a number of alternatives which are dependent on a number of factors. For purposes of discussion, the basic considerations can be classified into two, namely:

* effectivity of the program in terms of the attainment of the objectives to meet the needs

* implementation cost

The cost of the program is definitely an influencing factor in deciding the best strategy. Just like most engineering problems which have more than one solution, some "trade-off" has to be accepted. In other words, the effort shall be directed towards the adoption of an effective alternative (not necessarily the most effective) with the implementation cost as the constraining factor. If the most effective alternative is not economically prohibitive, then it is ideal.

Let us now discuss some of the issues that are relevant in making a program effective.

1. Organizational Structure

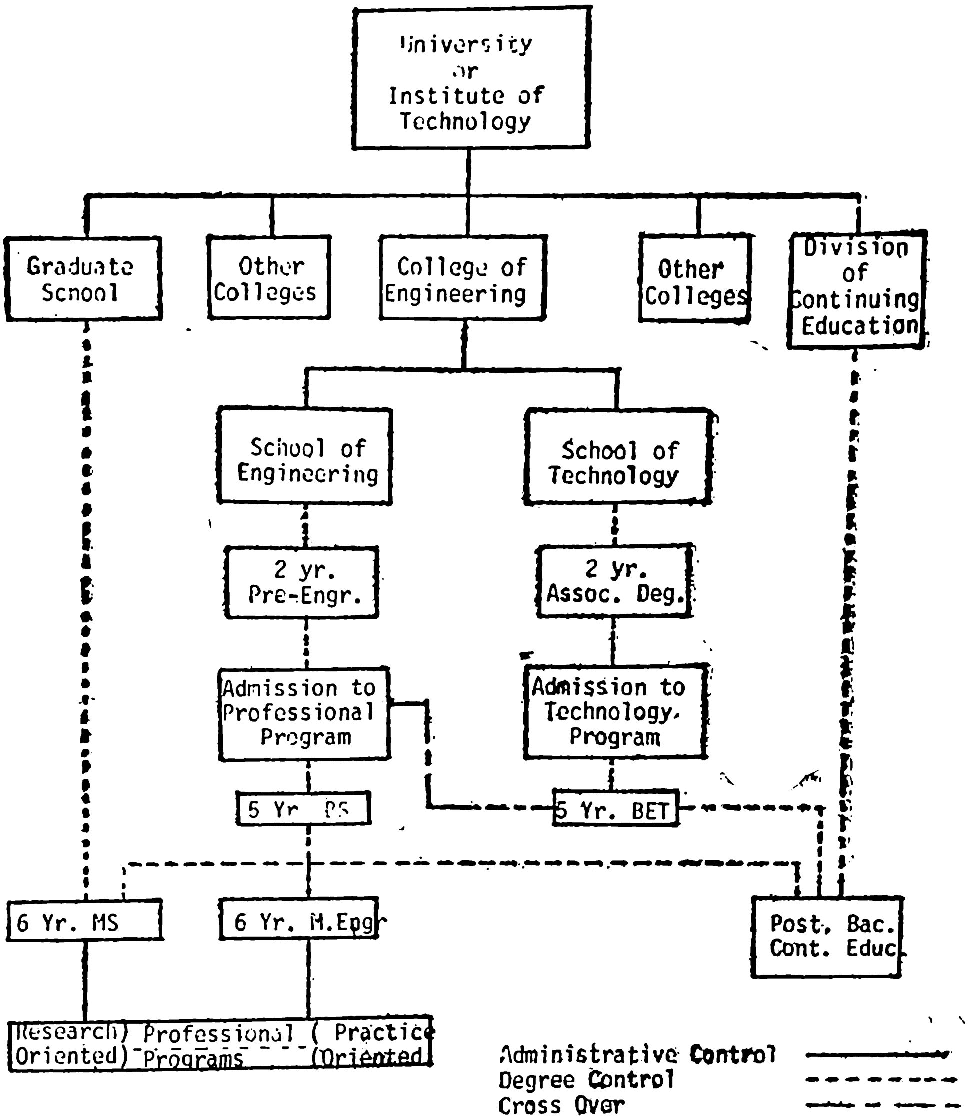
(a) If engineering technicians are being trained in direct support of an engineer, would it be desirable to have a link between engineering and engineering technology so that suitable cross-overs between the programs can be provided? For example, would the following organizational structure of professional schools and programs be desirable?

(b) The most common organizational set-up in universities is by discipline. However, it is observed that the problems of the world do not come organized according to discipline and therefore the organization of the university by discipline makes it remote and unresponsive. It is further observed that such insulation from reality, although welcomed by some teachers, makes the program less effective. Are we ready to initiate interdisciplinary programs although this means additional cost in handlin gand administration?

2. Program Content: The need for curricular reforms

If the essence of the engineering profession is "to create, to modify and to develop the environment of man to serve the needs as perceived in the society of the time", it is therefore not surprising that engineering courses shall always be under continuous review. Needless to say, there has been an evolutionary change in the perception and evaluation of the "environment" in which we should live and in the way we should exploit our natural resources during the last ten years. This has been reflected in —

* the increasing awareness of the finite nature of many resources
* the need for more economic and equitable use of resources
* recognition of the degradation and destruction already inflicted and the urgent need to halt and repair this damage
* the increasing need for developing alternative sources of energy
* the increasing preference for technologies developed indigenously from the local context, rather than transferred from alien settings.
* the increasing preference for technologies which are energy-conserving capital-saving and employment-generating, rather than energy-extravagant, capital-intensive, and labor-saving



* The increasing preference for energy-production technologies based on renewable rather than depletable, energy sources

All these changes have had consequences for the training of engineers, as well as other professions engaged in the development and modification of the environment. For example, in the energy area, one is no longer able to build continuing economic growth on cheap energy or a single-energy source. The engineer must realize rapidly that he will be called upon to think in terms of reducing waste, looking for the most economic solutions, exploring alternative sources of energy, developing new sources and resources. If the engineer's role is to serve man's needs "as perceived in the society of the time", he must be capable of responding to the new obligations placed on the engineering profession by society. These new demands from the industry and various crises may require the inclusion of new topics and in some cases new courses in the curriculum.

The energy problem is particularly relevant and significant today and the inclusion of the study of energy/resource and environmental issues in the University academic programs is imperative. Thus, the following changes can be considered:

(a) Institution of multidisciplinary technical courses on energy for undergraduate engineering programs covering such areas as
   * Energy conservation and management
   * Energy conversion technologies
   * Analysis of energy systems
   * Analysis of energy economics
   * Special problems on energy

(b) Institution of graduate courses in engineering and applied sciences

(c) Institution of an Energy Resources Training Program for the purpose of providing advanced training for practitioners in the field of conservation and management of energy resources

3. The need for effective teachers and for better criteria in teaching and grading

There are two essential ingredients that interact in the learning process; namely, qualified students and choice subject matter. For outstanding students who are capable of learning by themselves, they will learn without even going to school. For some, they have to go to school to take advantage of the physical and social environment only and will learn even without going to class which is normally under the guidance of a teacher. For most students, however, there is a need for someone who can excite the interaction. This someone is the teacher who acts as a catalyst. This is the role of the teacher whose effective teaching can make students to learn more and more quickly. If we believe in teaching, should not the teacher be required to have an education or training in pedagogy or andragogy? In addition, a good engineering program demands faculty who are able to correlate theory with application from actual experiences.

Since engineering programs are designed to prepare students for the practice of engineering at a professional level, there must be a correlation between college grades and performance of engineers in practice. However, under our present system, there seems to be a poor correlation between the behavior exhibited by a student to earn a good grade and what is required of him or her in professional practice. The atmosphere of the classroom is different from that of the outside world and in the treatment of problems, practical considerations such as economics, social impact, esthetics and human relations — which often outweigh the purely technical aspects of a problem — have often been distilled out of the problem or out of the course for reasons of simplicity or directness. Because of this situation, there are students with mediocre grades who become outstanding engineers or students with good grades who don't make good in practice. The following suggested "engineering scale" by William L. Larsen of Iowa State University may be considered with the corresponding meanings to the traditional letter grades:

Grade A: Substantial mastery of the subject matter. Mistakes in concept or application are rare. Ability to deal at the highest conceptual level in both the cognitive and affective realm of both technical and non-technical fields. Ability to formulate, translate and express ideas in both technical and non-technical language and thought patterns. Self-motivated, self-critical, self-learning; leads others; seeks and accomplishes beyond minimum requirements.

Grade B: Substantial mastery of the subject matter. Mistakes in concept or application are rare. Ability to deal at the highest conceptual level in both the cognitive and affective realms of both technical and non-technical fields with at least modest competence. Ability to formulate and express ideas in technical language and thought patterns and to understand ideas expressed in non-technical languages and thought patterns. When directed or encourage by others, can criticize and evaluate own work, learn independently, direct group effort, extend and amplify assigned work.

Grade C: Competent grasp of subject matter. Mistakes in concept or application not serious or frequent enough to endanger life or property. Usually can be relied on to produce sound competent work under supervision and to express the results in technical language. Limited ability to deal with abstractions and evaluations of technical material or higher levels of non-technical ideas. Can accomplish assigned work but has difficulty in self-criticism, independent study, setting directions for others or self. Exhibits minimum level of performance acceptable in professional practice.

Grade D: Modest grasp of subject matter. Mistakes in concepts or applications are serious or frequent enough to endanger life or property. Should work in the subject area only under close supervision. Cannot be relied on to express technical ideas clearly and precisely or to comprehend collegiate level ideas from non-technical areas. Should not be allowed to graduate with any significant number of weaknesses of this magnitude, especially in the major discipline.

Grade E: Inadequate grasp of subject matter. Serious mistakes in concepts or applications. Sufficiently incompetent that an attempt to do engineering work or to use knowledge in the subject area would constitute a hazard to the public. Formulation and expression of ideas in any realm are below good collegiate standards and inadequate for effective communication. Should not be allowed to graduate in any discipline without remedying deficiency.

The above suggestion is an attempt to have an "engineering scale" which is based on professional practice rather than academic tradition.

4. Optimum use of the engineering library as an applied learning laboratory

The engineering education program must have a reasonable integration of the library with engineering teaching. This integration is intended to promote —

* more purposeful utilization of the library by students
* improved preparation of advanced students for handling information retrieval once they are part of the industry
* maximization of library personnel services by making them active working partners of the educational team
* a new cooperative effort between teaching and library faculty toward more fully educating engineers
* library participation in the programs worked out between engineering schools and local industry.

5. Laboratory instruction as an integral part of engineering education

Laboratory facilities must be adequate to achieve the following objectives:

* To initiate the student to experimental engineering measurement and develop capabilities necessary to obtain design information. The emphasis is on how to get data, not on the data itself. Hence, the student should have practice in choosing the objective, devising the method, making the measurements, recording the data, checking the results, and deciding whether more data is needed.
* To acquaint the student with the real world. Most of the principles learned in the classroom and from textbooks are abstractions obtained from simplifying assumptions. These simplifications are desirable, but the student should obtain a realization of the magnitude of the difference between the abstraction and the real world.
* To develop the habit of thinking of engineering concepts in terms of physical operations. By thinking in terms of physical objects and operations, one can probably see other uses or combinations leading to new designs.

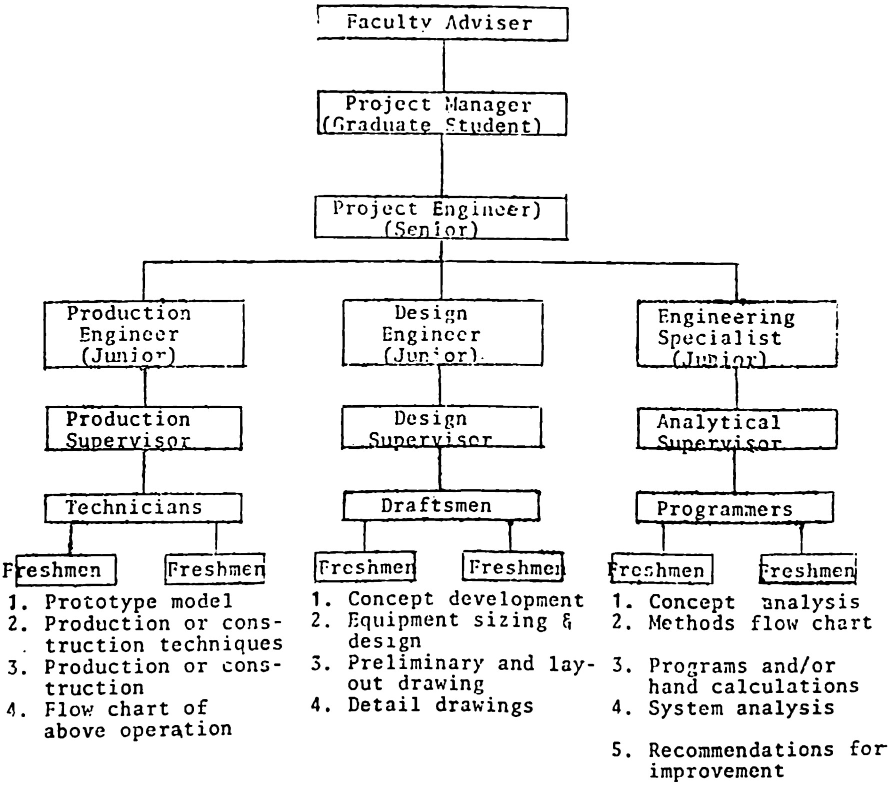
Other objectives may be defined under some circumstances and appropriate facilities must be provided to meet them.

6. Consideration of the vertical integrated design group. In line with the objective of engineering education program to prepare students for the practice of engineering at a professional level, we may consider the so-called Vertical Integrated Design Group (VIDG) concept in engineering education. The VIDG refers to a group of freshmen through graduate students who are working in an integrated design setting on a real engineering problem. Shown in the figure is the VIDG integrated design group organization and responsibilities. Projects undertaken by the VIDG may be a problem proposed by the industry. The participant from industry may be requested to cover part of the expenses involved in the project, including costs of materials and supplies, small pieces of equipment, travel and secretarial work. Similar tie-ups with the industry must be explored to lessen the gap between engineering education and the practice of the profession. (See figure of VIDC on page 12.)

7. The need for continuous education

As previously mentioned, the University must consider it as its responsibility to develop students in their formative years into continuous learners. This means that the University must be able to provide opportunities for continuing education. It has to be recognized that as society changes, its needs change. Correspondingly, the engineer must be capable of responding to the new obligations placed on his profession by society. The key to adaptability is education — continuing education.

Consideration of the above-mentioned ideas and adoption of a combination of anyone of them may lead to a more effective as well as a reasonably economical alternative engineering education program. As emphasized in this discussion, there are a number of strategies that may be considered in achieving the defined objectives of an engineering education program which is designed to meet a given need.


Faculty Adviser
Project Manager (Graduate Student)
Project Engineer) (Senior)
Production Engineer (Junior)
Design Engineer (Junior)
Engineering Specialist (Junior)
Production Supervisor
Design Supervisor
Analytical Supervisor
Technicians
Draftsmen
Programmers
Freshmen
Freshmen
Freshmen
Freshmen
Freshmen
Freshmen
1. Prototype model
2. Production or construction techniques
3. Production or construction
4. Flow chart of above operation
1. Concept development
2. Equipment sizing & design
3. Preliminary and layout drawing
4. Detail drawings
1. Concept analysis
2. Methods flow chart
3. Programs and/or hand calculations
4. System analysis
5. Recommendations for improvement