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ABSTRACT

This paper discusses the need for engineering education to address research and development, applied research, and technology transfer. It is important that engineering education considers as a major objective for engineering students the need of bridging the gap between what is produced in laboratories and the full scale of industrial production. Market demand should also be considered in terms of quality and price of offered products. (Contains 11 references.) (Author/WRM)

ENGINEERING THE TECHNOLOGY

Basic conditions to transfer technology innovation to industrial production

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Abstract *- In the introduction of the folder on ICEE 98 – Progress Through Partnership: Strengthening Alliances, it is emphasized that, quote: the pace at which scientific discoveries transform into technologies, and the rate at these technologies diffuse through the global market place, has changed the concepts and requirements of engineering education, unquote, which motivates the present's paper author to bring forth the importance of the concepts and related matter on how to transfer technology innovations from R&D to Production, considering the market acceptance of such innovations, or in the other hand, the market pull of needed innovations which goes upstream in the direction of R&D Centers, to be developed or, up-graded.*

It is must that engineering education considers as a major objective, for engineering students, the need of properly fulfillment of the gap between of what is produced in laboratories, in terms of bench and/or pilot scale, and the full scale of industrial production, considering the market demand in terms of quality and price of the offered products.

Preliminary Approach

The intention of this dissertation is to present a significant aspect of the "raison-d'être" of engineering education for the benefit of the engineering profession; in other words, the major objectives that is supposed to be attained along the extensive line of different types of engineering jobs (from applied research to production) that should be properly fulfilled by the engineers to be, in the near future.

Probably one of the most challengeable liason modes for the different steps of the engineering jobs is the one between applied research (with technology engineers) and basic design (with design engineers) that should then be added to others engineering jobs such as detailed design and technical and economic feasibities studies of different enterprises (this phase prior to construction and operation of an enterprise is known as the "enterprise in paper").

In the so called highly industrialized countries, specially in the United States of America, it is currently said that the number of engineers associated to applied research of development added to the ones in engineering design, is two-fold the number of the others engineers associated to construction and operation. Which enhances the importance that the first group of engineers attributes to the "enterprise in paper".

Working in applied research laboratories (bench-scale), pilot plants or developing prototypes in R&D institutions, or in engineering offices interfacing with these R&D institutions, and producing by themselves, basic designs in computers and/or drawing boards plus feasibilities studies, this group of highly classified professional engineers feels to a great degree gratified by the work they perform.

The present dissertation tries to emphasize the importance of adapting the engineering needs to the engineering curricula in order to assure a proper engineering education aiming at the above mentioned phase of the engineering profession that is, R&D and Design work, through concepts, definition and recommendations.

It is the author's hope that what is in here disclosed will help to motivate engineering educators, specially for the considered engineering areas as a mean to present to their engineering students what they should expected in their future jobs, in terms of professional opportunities and accomplishments, in the areas of applied research and development, and engineering design. An, also to help the professors of engineering classes to prepare then curriculum and lectures so as to bring their engineering students for their future responsibilities in the jobs that should be properly fulfilled by the future professional engineers.

1. Introduction

Technology today is associated with modernism in the sense of better quality – products and services – (related to cost/benefit) and, particularly, with globalization. Everybody, from laymen to scientists speaks about technology, which is properly used but sometimes abused. It is generally presented either in the strict sense of applied science or in a more ample sense, associated_ with social and/or political aspects (benefits).

Aimed to be properly used, by whom innovates the technology, many times they cannot impart the new technology developed in laboratory scale to the proper economic application. On the other hand, the new technology (specially the ones which remains in laboratory scale) might be promoted as an worldwide solution by those who uses it for unconfessed reasons, or simply, by incompetence.

Between these limits one might be looking forward for a proper relationship of cause and effect that the said technology brings forth.

In other words, technology is not an end by itself but means to be transformed in an economic reality.

Consequently what has to be pursued is a one technology demanded, considering its own merits and limitations, to be implemented in an industrial complex, based upon proper location and/or urban, human, financial and market requirements, in existence in the community that will absorve it.

What the author pretends in the present dissertation is to locate and analyse the more representative links between the long and complex chain between de R&D Center, generator of the technology and the industry that is going to used it in its production process.

The connection between these major links it is only possible by engineering the technology that one pretends to transfer to the production lines.

Finally, what should be most important for those who are integrated to the said chain is to minimized the possible failure of the new technology, by doing their best to assure to the proper technology integration to production process. The technology properly engineered tends to diminish those risks. The technology thus engineered is part of the technological package which reaches the market with success.

2. Concepts and Definitions

Science – a branch of study in which facts are observed and classified, and, usually quantitative laws are formulated and verified; involves the application of mathematical reasoning and data analysis to natural phenomena[(1)].

Technology - systematic knowledge of and its application to industrial processes; closely related to engineering and science (1).

Development - the work required to determine the best production technics to bring a new process or a piece of equipment to the production stage.

Whereas applied research pursues technology innovation within laboratory and/or pilot unit scale, technology development means the confirmation of the said innovation in the industrial/commercial scale.

Industrial technology means applied science, that is the exercise of proper application of theories and/or scientific principles, confirmed through experiments in different scales (bench, pilot, prototypes or semi-industrial), to industrial production or to industrial products, and cybernetics systems (opened or closed), patented protected, or not. Thus the expressions: "process engineering", "product engineering" and "systems engineering" which represents respectively the intermediate step to materialize the developed technology into an industrial plant, an equipment and/or machinery or in a macro or minisystem (electrical, electronic, hydraulic, mechanical, etc.).

Basic Design (process) - it is a preliminary design that will support a detailed design of a process industry. To execute a basic design means to engineering a technology, already proved in a small scale (bench and/or pilot unit), for an industrial scale with an justifiable economic size.

Technology Package - it comprehends the technology proven in bench and/or pilot unit scale, if possible properly protected by patent and/or patents, associated with the competent basic design in the dimension of the correspondent process industry.

Engineering the Technology comprehends the execution of the basic design (process engineering) or a prototype design (machinery or equipment), from smaller scales (bench or pilot unit) to industrial dimension. The technical linkage makes possible that the technology developed can be presented by the engineer of the basic design to the possible entrepreneur, with proper data (in the adequate scale for the future industry) needed for a technical and economical feasibility study (cost/benefit analysis) so that the entrepreneur himself might decide to construct, or not, the proposed industry, considering the risks he has to assume. This dialogue would be very difficult to be effective if developed between the technologists (who doesn't know how much will cost the future industry) and the entrepreneur (which decision will depend basically in the cost/benefit of the future industry).

Resuming, technology will reach practical results in economical and financial terms after being properly engineered, otherwise the future industry cannot be valued in monetary terms.

It is well known that scientific development in their natural environment, that is the University Scientific Research Institutes associated to the Research & Development Centers, autonomous or dependent (third parties), they effectively fertilizes the production sector only if the technology so developed is properly engineered.

Scientific knowledge gives support to applied research, which develops the innovated technology on bench, pilot unit or prototype scales towards the proper maturity (that is in the industrial scale) after being engineered. Without an adequate basic design (process) or a prototype design it is not advisable to look forward for an industrial/commercial dimension. The risks to be assumed by an entrepreneur that decides to implement it, without the necessary care or concern, might lead to a and disastrous adventure.

Actually, the industrial/commercial dimension defined by engineering the technology (process or product) is the one which permits the definition of costs, investments, profitability and return on investment that the smaller scales (bench and/or pilot unit and/or prototype) cannot garantee. It is valid to remember that the parameters of an industry (process or product) doesn't varies linearly. The steps to be covered by applied research (bench, pilot unit of prototype) they are not covered by caprice or in vain, but above all in the sense to minimize the risks that are going to be taken by the one who will

[(1)] Dictionary of Scientific and Technical Terms, McGraw-Hill.

industrializes the technology innovation.

In this manner, the major concern of this dissertation is to present to its readers the interdependence of science, technology and engineering in order to assure the effectiveness and the efficiency (in terms of cost/benefit) of a new industrial process or a new product (machine, equipment, etc.) that was borned from the inventiveness or, the man's ingenuity.

3. The Chain: Research and Development Center and the Industrial Enterprise

Think about a Matrix Diagram,where the inter-relations between "what to do" and "whom is going to do", from the conceptual phase down to the start-up of the industry. In this chain, companies where managers and employers work together, are identified, to help the understanding of the inter-relationship between, each pair of links to R&D Center to the industrial enterprise.

The Enterprises

Each one, as an individual company, has different objectives or missions; each one facing a different market and a distinctive commercial and/or socio-economics risks. The objectives from each one of the enterprises might even being conflictive.

As it happens, in the case of R&D Centers that executes basic design competing with engineering companies, or construction companies that executes detailed design. There are also engineering companies that develops prototypes of equipment or machinery and gets eventually into product engineering when, in the understanding of equipment and/or machinery industry these activities are pertinent to them by vocation. Finally, there are also process industries integrating in their organizations design divisions and eventually small centers of R&D. On the other hand, the success measurements of those companies are not necessarily only in the financial aspect. As the example of R&D Centers which are supported by non-profit foundations, whereas for the other types of organizations, profit is directed associated to their survival. In some instances and in some countries there are companies state owned, primarily for political reasons (such as weapons).

Research & Development Centers

The research and development center (applied research and technology development) pursues the technological innovation, either stimulated through basic research (basic or theoretical research) or demanded by problems emerged from the everyday operation of the process industry or many times from the market pull, itself. The R&D is responsible to produce the necessary and qualified data or parameters of the physical-chemical process development in bench and/or pilot unit scale, aiming always to optimize the future operational conditions of the referred innovate process.

Engineering Companies

The engineering company must have the capacity to transform the physical-chemical parameters of the proposed process into a basic engineering design (in other words, the engineering of the technology). This company might supervise or actually develop the prototypes of the critical machinery and/or equipment of the process industry, which the basic design was executed by itself.

Certainly the engineering company can itself carry out the detailed engineering design of the said process industry and also to supervises its implementation, in terms of civil construction and industrial erecting.

Process Industry

The process industry manufactures the products (product-mix) defined by the elected process, looking always forward to maximize the respective investment return (based upon the cost/benefit obtained).

Depending on its size, the process industry considered might contribute specifically in the technology area either through an R&D integrated to itself and what it dominates in terms of technology and what it might disseminates for others R&D Centers, in terms of operation and maintenance of a particularly technology properly developed and integrated to a production process of this individual industry.

Equipment and/or Machinery Industry

These industries manufactures, generally by special orders, the equipment and/or machinery which data sheets are part of the processe basic design. They might also manufacture prototypes under the supervision of the engineering company responsible for the mentioned process basic design. Many times they themselves develops the new equipment and/or machinery prototypes. Generally these industries are responsible for the product engineering and production planning of the equipment and/or machinery they manufacture.

Civil Construction and/or Industrial Erecting Companies

These companies that might have specialists in either of these professional areas, they can possible be incorporated in a unique company that executes civil construction and industrial erecting, inside or outside battery limits of the considered process industry.

In general they dialogue permanently with the company which performs the construction management (possible acting as its third party) and also,constantly with the engineering company responsible for the basic and/or detailed engineering design of the process industry being implemented.

Management Consultant Companies

These companies acts as catalysts, by promoting the integration and implementation of the industrial enterprises. They direct, supervises and coordinates, acting in the name of the entrepreneur of what should be accomplished in terms of engineering, procurement and construction of an industrial complex.

The Specialist

The specialists, beginning with the scientists (scientific, theoretical or basic research), then the ones who performs applied research and technology development, followed by the engineers (design, construction, industrial erecting and operation), each one of them has distinct motivation and professional achievements. What might be gratifying to one of them will not be necessarily gratifying to the others. The product of their professional activities is distinctively different.

The science investigation depends on the ambient where it is performed. It will be mandatory the existence of a special atmosphere that involves the scientists assuring them the liberty to create.

Science itself is inadequate to market demand.

In the other hand technology depends strongly on marketing demand or market pull and, also, from political decision (that was the case of the A-bomb developed during the World War II for political decision).

Applied research pursing a new technology, generally depends on significant investments associated with the capacity of assuming heavy risks by the ones who are developing them. Engineering is market oriented. Its success is heavily dependent upon its capacity to select and absorve technologies (by engineering them) and in some instances (turn-key contracts for developing industrial complexes) to raise substantial amount of money to be invested plus the needed human resources.

Normally the risks associated to engineering work are smaller then the ones with respect to technology.

In the other end the industry or industrial activity besides being market oriented in principle its major objective of their owners is the return on the investment applied to the business itself and with that respect accepting the risks involved with it.

The Scientist

The product of the scientist activity is, in general, a scientific paper associated with an oral dissertation. These papers describes physical-chemical and deterministic and/or probabilistic mathematical models created or developed by the scientist itself. The scientific language is normally hermetic; very few persons (generally, only others scientists in the same scientific area) has access to scientific work. Notwithstanding, the wish of the scientist is that his scientific message is received by all the others fellow-scientists. The acceptance of this creativeness after debating his own thesis with his par and its possible disclosure in the international level might be his best reward.

In the other hand when he sees that his touch of genius has echoed and became the lever for the development of a new process or a new product, through the help of applied research followed by engineering, the resultant proven technology, is his most outstanding commendation. After all, yet being a rare species as a human being, he is above all a human being concerned about his equals. The archetype of the scientist is disinterested in possession; he feels professionally gratified in creating scientific opportunities, provide his existence needs are properly fulfilled.

The Technologist

The product of the technologist activity is in geral a report about the physical-chemical and mechanical processes and/or products developed by himself, either in bench and/or pilot unit scale or, prototype. These reports are supported by abacus, diagrams, nomograms, flow-sheets, curves, tables, etc. that indicates, within the critical limits of the experiments, the routes, reaction's speeds, energy balances, materials balance, static's and dynamics loads and other pertinent data that characterizes the qualitative and quantitative aspects of a process, before being industrialized, and/or a product's prototype.

The language of the technologist is less hermetic than his scientist fellow. Its dissemination reaches a much larger public than the one related to the scientist.

Nevertheless, the mentioned dissemination, is rather restricted. The reason for that restriction is associated to the value of the technological product. In the end the innovated technology can create or developed processes and/or products that reaches the consumption market were its going to fight competitors for the share of this market. Being that the assumption, the revealing or disclosure of a new technology is restricted because the technological product has an economic value so it can be marketable.

In the other hand, the technologist, more identified with the economic value of the product that he intends to create and developed, has under the aspect of the remuneration and/or share of the commercial results obtained, a very great incentive. In that case, his professional accomplishment is stimulated by his possibility in the development of process and/or products that will be industrialized. As the scientist he will fill gratified in trying to contribute for the society as whole, in its tentative to help to produce goods for the benefit of everyone concerned (and, if possible, of the money returned on the marketable products, patent protected).

The Engineer

The product of the engineer's activity is better known. That will be the case of the basic and/or detailed design and the construction of the industrial enterprise, being a steel mill, and industrial plant, a refinery, a petrochemical unit. On the other hand, he might also execute the prototype design an its manufacture, the production planning of the industry itself and its operation and maintenance, or finally in developing electric and/or electronic, hydraulic, transportation and telecommunications systems.

As the engineer gets away from the interface between the applied research (producer of the technology) and the basic design, going through detailed design, then construction and manufacturing, his professional liberty degrees will shrink because in this last frontier his engineering actions are attached to rigid specifications, standards, methods and procedures, whereas in the frontier of technology development and its engineering has comparatively speaking more degrees of professional liberty.

The engineer is gratified in a wholesome aspect the moment he feels that was the action he has taken that resulted in an undertaking or an machine and/or equipment, engineered by him. The economics sense, its intimacy with cost, the touch of quality, safetyness and respect for ecology draws the engineer's profile. He seems to be nearer than his antecessors – the technologist and the scientist – to the sensation of being the artifice more directly responsible for everyone (common) concerned well-being. Actually he had implemented the undertaking and now operates and maintains it.

The relation between the number of engineers for million of inhabitants is about three times greater in the industrialized countries than the ones from the so called third world.

It is admitted that in the industrialized countries 2/3 of its engineers are associated to applied research and technology development and/or basic design.

The other third are identified with the other engineering area such as detailed design, civil construction and industrial erecting operation and maintenance and marketing.

In the third world countries these relations are in a reverted position. Only 1/3 of engineers in R&D and the other 2/3, in construction, etc.

4. R&D Centers and Engineering firms

The previous chapter was intended to disclose the institutions and individuals who are part of the long and complex chain from the R&D Centers to the Industrial Complexes. The sugested matrix should present the relationship between all the organizations concerned and their objectives towards their major mission, that is the implementation of an undertaking that involves them all.

The present dissertation pretends to go deeper in the aspects of the ones associated to the mentioned matrix, so what will follow in this text is going to give more elements with respect to R&D Centers and Engineering Companies, looking forward to the importance of the proper arrangement of a technology package.

Research and Development Center

The R&D center, independent or captive (university, industry, engineering company, etc.), must have enough qualified human, material and financial resources, identified with its own vocations and know-how in some special areas of applied research, aiming at:

a) upgrading of already dominated technologies that is, technologies integrated to processes, in plain operational matureness, evaluated through the feed back of the individual industrial enterprise to the R&D Center (supposing that it has a pilot-unit for that purpose for the so called scale-down). Alterations or innovation stimulated by the said evaluation considering the need of eventual substitutions of raw-materials, catalysts or eventually the process modernizing can be tested in the pilot-unit (in scale-down basis) and then in the up-graded condition returned to the industrial enterprise itself (in scale-up basis), if the up-graded measures are proven to be effective. This scale-down, scale-up, procedures obliges the R&D Center to a close contact with the industrial enterprise so as to be acquainted with the performance details (quantitative and qualitative) of the industry operational day-by-day. This interface makes mandatory the technical dialogue with the maintenance teams of industrial enterprise, on the assumption that these maintenance professionals are one of the best suppliers of needed of process alterations and/or technologies innovations.
b) Technology creativeness – that is, technologies purposely developed or discovered by chance (serendipity: "shoot at the target one sees and killed the one which is not be seeing"). Though each one of them must be tested in terms of feasibility. So, besides the technology innovation being demonstrated in bench scale, it is mandatory that it should be tested and proved in pilot unit scale to have an acceptable credibility, in order to be engineered.

Engineering Companies

These companies are generally incorporated to execute basic and/or detailed design, and in many instances, consulting and/or construction management and procurement. Notwithstanding the fact that some few R&D centers have themselves basic engineering design departments.

Being the basic design the confirmation of the synthesis of all scientific-technical aspects of the engineering science, its proper execution will depend heavily upon how its engineers are engaged with basic design itself and applied research (pilot-units) on the other hand.

In this text is understandable that these engineers are allocated in the Basic Design Department of an Engineering Company or in a R&D Center.

Basic Design Department

Besides the relationship between basic design and pilot unit its is also mandatory its intimate association with the detailing design, which includes the specifications of the machinery and equipment of the so called "inside battery limits" of the industrial enterprise.

The execution of basic design must observed the following:

a) Basic design for already dominated technologies, but to be up-graded in a pilot unit.

The execution of this basic design obliges the Basic Design Department to its close association with the industrial enterprise that it is in operation. The up-graded technology born from the industry needs, conditioned the basic design because, obviously, it restricts its freedom's degrees. The design engineers assists the technologists in the "scale-down" and then in the "scale-up" in the links from industry to pilot unit and then from pilot unit back to industry. The contiguity between the design, operation and maintenance engineers with the technologists is the major responsible for the basic design to be executed by engineering the up-grading of a technology already dominated.

b) Basic design for technologies innovations directly developed in R&D Centers (intentionally or by chance).

In that case, the execution of the basic design, recommends the drawing together of basic designers with technologists around the pilot unit, and subsequently, in a semi-industrial unit (when and if it will be the case). The closeness of these professionals in the operation of these units for sure will go to give a good hand to the execution of the basic design of the innovated technology. The problem to be resolved deals with performance of the data and/or parameters which defines the process considering the steps that should be taken in the scale-up from the pilot and/or semi-industrial units to the final industrial operational scale. The stepping up of these scales (some data and/or parameters are not linear in their stepping up) brings to the basic design engineers a considerable responsibility. Once the basic design is already made-up, and written the design's memory the basis of the future industrial enterprise is launched without future possibilities of significant corrections.

5. The Technology Package

5.1. The assembly of a technology package has to consider the following key-points:

a) The importance of the scale dimension that goes together with the developing of a technology until it will be engineered through the basic design.

Scale is being concepted as a dimension, within a level or basis in which a technology is developed, that can varies from bench scale to a pilot unit scale or to a semi-industrial scale up to the design of a demonstration plant. The development of a new technology has to go normally through the bench and pilot unit scale and if possible or recommended through the semi-industrial scale. Really everything depends on the relation cost/benefit to help the entrepreneur to decide in assuming the risks of the future industrial enterprise. In general the final risk (considered the engineered technology) is to be taken step by step through sequential procedures assisted by tests and performance procedures, scale by scale to reach the validity of the considered new technology. In the end, the challenge to be faced in the scale changes is the non-linear behavior of certain parameters which defines the process technology. This is major reason for the needed above mentioned sequential procedure.

b) The written memory of a basic design has to consider the following documents, data and drawings:
   - general conception of the technology proposed and its relationship with the industrial enterprise, inducing its patent protection
   - detailed description and the process's flow-sheet
   - patents covering the units (machinery and/or process equipment), including catalysts
   - codes and standards applicable to the process
   - preliminary director plan
   - general lay-out planning and respective drawings
   - plant architecture preliminary design
   - civil works preliminary design
   - specifications and materials balance (raw-materials and others)
   - final products and associated products plus the production refuses or rejections
   - types of energy used in the plant with the competent balance of energy
   - piping and instrumentation diagrams
   - list of data-sheets of the major equipment's and machinery accompanied by the correspondent utilities data-sheets
   - electrical, steam and hydraulic lines diagrams
   - preliminary design of the utilities (outside battery limits)
   - operations manual of the plant

5.2. The Technology Package should presents to its buyer the following elements:

a) Proper data, technical and financial information plus guaranties, necessary to the execution of the economic, financial and technical feasibility studies of the planned industrial enterprise. These studies are the major elements of conviction for the decision making of the entrepreneur to proceed in the construction and future operation of the industrial enterprise in question. They can also support the needed investments for the said industrial enterprise.

b) In the other hand, it can furnish the needed information to prepare the proper commercial and technical documentation for the bidding of the necessary implementation services of the industrial enterprise, that is, the detailed engineering design and the supply of the critical equipment and machinery.

5.3. The interface problems: "Technology and Basic Design"

In terms of cost/benefit of the performance of the above mentioned problem, the following negative aspects should be considered relevant:

a) Lack of capacity to select the proper technology or to overcome the deficiencies of the chosen technology.
b) Lack of experience of the country benefited by the technology transferred from a highly developed country, in order to adapt the respective basic design (engineering the technology) to the specific needs of the receiver country, including its capacity in furnishing the equipment and/or machinery designed for that specific industrial enterprise.
c) Lack of capacity related to the engincering of the technology considered.
d) Lack of capacity to develop the necessary support of the considered technology, looking forward to maximize the relationship between the supplier and the receiver of the transferred technology.
e) Lack of experience in the problems involving performance guaranties related to the considered technology, for the future undertaking.

5.4. Trying to correct the above mentioned possible deficiencies, some measures are here - by recommended:

a) Develop and consequently assure the capacity of the receiving part in develop process engineering basic design for the transferred technology.
b) Acceptable domain of the technology considered.
c) Plain domain of the technical language of the country's licensor and/or supplier of the technology considered.

Post-Scriptum: The scientific and technological knowledge are the most important motors of future events; that is what is being expected to be. This binomial helps to shape the future. Policies and ideologies can be modified, but science discovering and technology innovations, once liberated, they don't return to the laboratories and/or to design offices (except to be modernized or to be upgraded). Therefore, the strategists who devot their time do study and develop strategic scenarios should follow very close the new areas of knowledge in chemistry and physics, computerization, biotechnology, new materials, basic design, automation and robotics, micro-clectronics and other key-areas of knowledge development, as their special mission. The Universities and the Research & Development institutions have to bore this significant leadership, i.e. the majors boosters to promote science and technology, whereas the engineering services firms and industries, the implementation of technology innovations generated in R&D Institutions through: basic and detailed design, civil works, procurement, industrial erecting, start-up, operation and maintenance and, eventually, the demand for technology upgrading.[1]

[1] Adapted from Peter Schwartz's. The Art of the Long View, Doubleday/Currency, New York, 1991.

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