Session 3202

# An Integrated Approach to Unify the Technical Dimension of Engineering Education

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Summary

This paper proposes an integrated approach to unify the technical dimension of engineering education. Integrating the technical dimension of engineering education is a necessary step towards effectively implementing EC 2000, adopted by the Accreditation Board for Engineering and Technology (ABET). Technical dimension, in this context, deals with the scientific and engineering concepts and methods that are used in the design, the analysis, and the solution of engineering problems. The integrated view is based on three concepts. First, the education system is a feedback dynamic control system. Second, the engineering design method is utilized to design the integrated education system. Third, the total lab concept is employed to unify the apparent diversities in engineering fields and remedy some of the deficiencies of the traditional education system. The total lab concept combines the basic tools of the theoretical analysis, the experimental measurements, the computation, and the visualization in the engineering curriculum. The suggested courseware is composed of three modules. The first module covers the common scientific background required for all engineers. This module will be designed to improve the skills and abilities needed in the future engineering workplace. The second module combines many engineering courses of similar nature. This combination will reduce redundancy and the number of courses required for graduation. The third module is a detailed application of the above two modules for students specializing in a certain field of engineering such as AE, CE, EE, ME, etc. This paper claims that this reform will help to replace teaching by learning and create environment that motivate students to creative and critical thinking, problem solving, and multidisciplinary learning. Criteria 2 and 3 of EC 2000 are related to these goals. Engineering practice and social issues are other dimensions of engineering and should be integrated into the education system for future engineers.

## 1. Background and Motivation

The background and motivation of the present work is based on ideas and concepts discussed in references 1-17. Main ideas, observations and concepts from these references will be used to introduce the main theme of the present work.

Technology has prompted most of changes in our society and will play an even larger role in the future. There are many factors in the world today that will shape the future of engineering education. The rapid changes of skills and technical abilities required of engineers, the new fields of engineering, the expanding spheres of engineering knowledge, the efficient use of the methods and tools for design and problem solving all these necessitate changes in engineering curriculum. In addition to that, the rapid developments in the fields of computer sciences, information technology, nanotechnology put pressure on engineering students to take courses of these subjects. The limitation of time necessary to graduate the increasing number of knowledge required, and the new skills necessary for the new engineer represent a difficult challenge for engineering education.

The cross-fertilization of many engineering disciplines and the trend of multidisciplinary education is another issue that needs to be implemented in an engineering curriculum. If changes need to be made in engineering education, it might be suitable to rethink of the philosophy of education in general, and engineering education in particular. In this respect, we need to answer the following questions: Is there a philosophy of engineering education that many institutions of higher education implement, develop curriculum based on it, and monitor its dynamics? If this philosophy exists what is the role this philosophy has played and will play in the creation of professional engineers? Are there evaluation studies to show the success or failure of this philosophy to produce professional engineers?

Whether there are specific answers to the above questions or not, it looks like that the philosophy of education has changed from the past to the present and will change in the future. The future of higher education, for engineers in the 21$^{st}$ century, can be envisaged as different from its past and present. Whether this will be better or worse depends on what is perceived as the best way of managing change in education. There is already a marked transition in the approach, objectives and subject matter of engineering courses to cater for new technologies and industrial needs. The following points will help to pave the road to reform the philosophy of engineering education[1-3].

The falling number in students' entry into science and engineering courses is a symptomatic of the prevailing mood in the new generation of students. While the demand for engineering is growing, the percentage of college graduates with engineering degree is shrinking. Many potential engineers are turned off by the poor quality of mathematics and science teaching in school system. It is shocking that the top 12$^{th}$ grade students in US score at the bottom in math and science compared to their peers in foreign countries. Alienation from engineering and science begins early for many students who might eventually, in their maturity, be active decision-makers in policy.

High technological advances require engineers with satisfactory levels of math and science. Students are rarely motivated to appreciate the value of studying math and science. Math, science and engineering courses are intellectually more demanding and require more application and study than some other fields of study. Our modern society needs problem solvers. Mathematics, science and engineering are integral part for problem solving methods. Improving the problem solving skills will improve the quality of life in US and around the world.

In addition to that, expanding spheres of knowledge and technology, in all fields of engineering, requires more time and courses for undergraduates. This can not be achieved, with the time limit of college education, unless new concepts for engineering education are introduced. In a global economy, jobs will go to those with the required skills. A shrinking job base, because of a technical skills gap, will mean a lower standard of living not just for engineers and other technical workers but for all Americans. The development of higher education for engineer in this country will undoubtedly include the need to respond to the changing nature of engineering itself.

At this stage of education development, we need to rethink of new concepts that help engineers to learn more subjects, have a reasonable knowledge of additional areas of engineering, prepare themselves for the new job market, and to acquire more skills without increasing the time necessary for graduation. Any change in engineering education must take into consideration the different dimensions of engineering, which are the technical knowledge and skills, the practices of the professional engineering, and the social dimensions[4-17]

To implement ideas of multidisciplinary engineering, which combine different and various fields of engineering, to add more materials of new engineering findings, and to keep the time span of undergraduate degree, the course structure must be reviewed and restructured. New concepts must be developed to reduce the number of courses, to change the contents, and to modify the methods of teaching. No one knows if the engineers will really need all the coursework, that they used to take in our conventional engineering schools, before entering the workplace. In this respect, students should master a wide range of skills in order to fit the rapid changes in the workplace. Also, they should be able to distinguish between science, mathematics, physics, engineering and technology. They should know the differences between the roles, functions and principles of these subjects.

## 2. The Engineering Education in 21$^{st}$ Century

The ABET EC 2000 is an important item in discussing Engineering education[18]. Acceptance of EC 2000 needs a revision of the existing engineering curriculum to modify it for an effective implementation of ABET EC 2000. A new engineering education system is expected to be flexible and able to adapt new changes in objectives, goals in a dynamic fashion. This paper suggests that integrating the technical dimension, the social dimension and the engineering practices dimension, as interactive feedback dynamic system, can improve the engineering education system. This improvement will produce the engineers without prolonging the time for graduation.

Restructuring the engineering education system requires reviewing the philosophy of engineering education, unifying the technical dimension of engineering, reviewing the status of engineering profession practices in the curriculum development, introducing the social dimension, and employing a unifying approach to integrate these dimensions in one system. A dynamic self-assessment procedure is required to evaluate the working of the education system. Evaluation subsystem must utilize an automated procedure to measure the performance of the education system, on a systematic basis, to correct any deviations from the required goals of the system. This paper discusses the technical dimension of engineering education and suggests a new course structure that satisfies criteria 2 and 3 of EC 2000.

The first part of the paper gives some thought about the philosophy of engineering education in 21st century. The second part of the paper uses the block diagram of feedback control system to implement the above philosophy. The third part of the paper uses the design engineering concept to design the education system emphasizing the goals of the education and how to achieve it as a dynamic control process. Roles of curriculum, instructors, facilities and administration are considered as subsystem of the entire engineering education system. In the fourth part of the paper the total lab concept is introduced and used to design the new courses.

A suggested time frame, to complete the years of studies, is outlined as an example of the application of the unified approach. The first phase of engineering studies covers the basics skills needed for all engineers. In the next phase the skills and knowledge gained in the first phase will be expanded, detailed and applied for different fields of engineering. In the third phase, the total lab concept is used as a unifying tool for all engineering areas. This will help students to understand the relations of scientific tools to all engineering disciplines, relations between different disciplines, and prepare students for multidimensional studies. Also in this phase a unifying concept will be used to combine different courses with similar nature. This will help to reduce redundancy of repeated materials in different courses and help to add new application areas without prolonged the time of study. In the last phase, the students will specialize in AE, EE, CE, ME, etc after spending few semesters of foundation. This strategy will open the doors for the problem solving skills and will put the foundation of critical and creative thinking.

The suggested philosophy of engineering education considers engineering education as a dynamic control feedback system with well-defined input and measurable outputs. The input of the system is the ultimate goals of engineering education in this century. The outputs are the end results of the education system or the future engineers. The feedback links work in a dynamic fashion to correct any deviations from the desired results. This control system must weave the three dimensions of engineering education (technical, social, and engineering profession practices), in an interactive manner, into the curriculum. The educational system should combine holistic and serial thinking (step by step) when dealing with teaching and learning methodologies. Also, it should combine cognitive, behavioral, and social theories of learning to achieve its goals and focus on the concept of lifelong education. Education system should be flexible and adaptive (from control theory viewpoint). This means that the system should have a mechanism to predict changes in goals, objectives, skills, curriculum, etc and develop a scheme for correction. Assessment of students' achievements must include different and various methods to measure students' attitudes, skills, character, values, and abilities gained. The assessment procedure must be automated to save time and reduce cost. It should be used in a systematic periodic manner with minimum effort to display the results of evaluation.

The main elements of the educational system are the students, faculty, facilities, administration, curriculum, society, environment and the job market. These elements will be arranged as subsystems of the engineering education system in such a way to increase the probability of producing the desired engineers in the four years of engineering studies. The philosophy we suggest take this entire picture and review the nature, structure, roles of each element and the manner of interactions of these elements to achieve the goals of education. The main goal of engineering education is to produce an engineer with specific knowledge, skills, abilities and qualities. Some of the specific objectives can be derived from EC 2000.

The knowledge that the students will need for future jobs can no longer be predicted. Instead of focusing on knowledge, it is the attitude to learn skills, information processing, beliefs, critical thinking, creative thinking, and problem solving that will sustain the students into the future. Engineering education should produce students capable to process information and produce knowledge rather than retrieving information from memory. Information processing, problem solving, creative thinking, critical thinking, and teamwork are indispensable abilities for the future engineers.

Techniques of problem solving must be an integral part of engineering education. Modeling and simulation will be of great values as a tool for problem solving. Engineers should be trained to model diverse phenomena using engineering concepts. In solving problems, students must learn to utilize the theoretical, the experimental and the computational methods as simultaneous tools for understanding, analysis and design. Problem solving capabilities of engineering students should take into consideration the practice of engineering design processes. These include the iterative concept to reach solution and concept of the open endedness of solutions. The rooted idea of the uniqueness of solution must be changed.

To develop creative and critical thinking a deep understanding of the foundations of science and engineering principles is the first step. Students should be aware of the concepts of laws, theories, principles, hypotheses, and assumptions when dealing with a specific problem. As designers know, there are more than one solution for a specific problem, some solutions are wrong, some are right, some solutions are better than other solutions, and some solution are the best. Students must be trained to select answers based on well-defined criteria of optimality or the best.

3. An Integrated Approach to Unify the Technical Dimension

The suggested integrating approach considers the engineering education system as a dynamic feedback control system. Engineering design methodology is evoked to design and evaluate the working of the system. Technical dimension, in this paper, deals with the scientific and engineering principles, knowledge and skills that are used in design, analysis, and solution of engineering problems. These include the areas of mathematics, physics and all fields of engineering.

We can divide this dimension into four categories. The first category deals with the basic engineering knowledge of various fields (aerospace, electrical, mechanical, etc). The second category deals with the general skills of prospective engineers. Examples are problem solving skills, design skills, creative thinking and critical thinking skills. The third category deals with specific skills such as calculations, computations, designing and doing experiments. The fourth category deals with communication skills, team working skills, and organization skills. A large portion of EC 2000 deals with this dimension. Figure 1 shows a block diagram representation of the educational system.

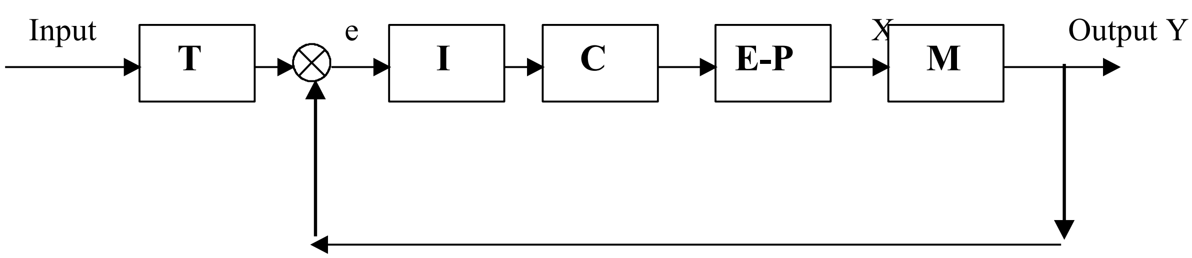


***Figure 1. Block Diagram of the Education System***

The input to the system is the goals of the desired educational system. The goals cover the three dimensions of engineering education. Our concern here is the goals of the technical dimension. Education takes time to produce results. Our concern here is the time required for learning process to produce graduates with the desired abilities. Engineering program takes almost four years, during these years the output, at any time Y, is the partial achievements of the desired goals. Block T, in figure 1, represents the process of transforming the general qualitative goals to a quantitative matrix of skills and knowledge bases. Curriculum developer and learning experts are the main elements of the transformation process. The comparison node in the figure compares the actual skills and knowledge base with the desired skills and knowledge. The deviation error, **e** in the figure, is used by the identification process (block **I** in the figure) to pinpoints the sources of deviation. Faculty and education psychologists are the main elements of block **I**. Block **C** in the figure is the controller. Faculty, administrators and students are the main elements of this block. The controller issues a control policy for the correction to improve the performance. The correction policy is the input to education processes (Block **E-P**). Correction policy will work to change all or parts of the education processes. The main elements of **E-P** are the curriculum, facilities, students, and instructors. The changes will be limited by economical and political constraints. The output of the **E-P** block is the learning state of the student **X,** which gives the important aspects of students' learning. Here **X** represents students' study habits, skills, abilities, and attitude towards learning and motivation. The measurement block **M** is responsible to produce quantitative measures of skills and knowledge **Y** gained during the learning process.

The first step in designing an educational system is to ask what the final outcome should be? Then the subsystems are designed to achieve that end. Selecting goals is not an individual task but collective effort. What are the goals of the technical dimension of engineering? What kind of engineer do we need? . Examples of agreeable goals are critical thinking, creative thinking, problem solving, ability to relate different fields of engineering or multidisciplinary view, learn how to learn, prolonged learning, how to think correctly, ability to absorb more engineering knowledge, leadership, teamwork, time management (efficient use of time), holistic and serial thinking, parallel and sequential working, and taking decisions. Policy makers, educators, designers of the educational materials, faculty, teachers, instructors, students, parents, administrators, curriculum developers, learning theories experts, and technology partners must ask themselves what are the goals of education. Communicating with one another to reach an agreement is a necessary step before progress can be made. If the goals are clear and well defined, polices to achieve these goals can be established, curriculum and education technology can be developed. Also, methods of instructions are selected and methods for evaluation and assessment are adopted.

The goals of technical dimension of engineering education as outlined above are general and qualitative. It describes the qualities of the end product, i.e. the future engineer of the system shown in figure 1. These general goals must go through transformation process that transform goals into abilities, skills, characters, and knowledge bases that can be observed and measured. This process will produce, for the technical dimension, the necessary skills and engineering knowledge. The main underlying hypothesis is that the above specific skills and knowledge gained in the learning process will be sufficient to produce an engineer with the desired qualities. Curriculum is responsible to implement the above skills in an engineering program.

Generally speaking a curriculum is a systematic plan to enhance leaning and to achieve certain goals. Therefore, we will define curriculum, from systems viewpoint, as an interactive feedback dynamic process to enhance learning and to achieve specific goals. The main interacting elements of the curriculum are ***objectives***, ***content***, ***instruction techniques*** and ***evaluation methods.***

Objectives of the curriculum are derived from the goals of engineering education. Thinking of the end product of engineering education is an essential step to design the engineering curriculum. Goals as expressed in form of skills, thinking habits and knowledge are cultivated in the labs and classrooms. Specific skills include mathematics skills, physics skills, computer skills, calculation skills, design skills, scientific method skills and communication skills. Communication skills deal with the speaking, technical writing, reading, and small group communication to solve problems. Engineering knowledge is divided into two categories. The first category focus on the basic engineering concepts and principles that all engineers need to learn. Examples are the modeling concepts, the simulation concepts, the concept of laws of nature, the basics of computation, experimentation and theoretical analysis. Unifying concepts for the fundamentals and principles of engineering sciences is necessary to integrate the technical dimension. The second category of engineering knowledge deals with the special engineering fields. Examples are aerospace, electrical, mechanical, chemical, civil, etc.

Content is the medium through which students will gain skills and subject matters. Content appears in the courses and syllabi. Total lab concept will be used as a tool to achieve the desired skills of the engineering knowledge. Switching from teaching to learning is a corner stone in instructional techniques. Teacher role should be changed to the role of an educator and should work in the lab or classroom with students as a movie director. Instead of memorizing different formulae, students should be aware of the nature and assumptions behind each formula. They should be trained to select the proper formula for the given problem and know how and when to apply it. Instead of memorizing knowledge, students should be trained to collect information and produce knowledge. This will help to create the sense of discovery in the minds of students.

4. The Total Lab Concept

The total lab concept[19] relies on combining the three methods of scientific research to tackle engineering problems efficiently. Understanding the problem, as the first step, can be achieved through investigating the linkage between the problem and phenomenon under study. The second step is the problem formulation using system concepts and modeling methodology. In this step, the concept of law is essential and the transformation of laws to equations and statements will be strengthened. Here the role of mathematics is fundamental. In the third step, students will be trained to solve problems using various techniques. In this step, the role of analytical thinking combined with the computational methods and experimental procedures is essential to solve problems and to validate the modeling. Theory, experiments and computer simulation will be used interactively or simultaneously in all these steps. The fourth and final step is the presentation of solution and communicating the results to other engineers. Here the information technology, multimedia, and computer tools of visualization and animation are essential.

4.1 Understanding Phase

Engineering students must be trained to use the scientific method properly. They must be competent in using and mastering the following terms: observation, description, classification, definition, abstraction, theory construction, laws, principles, rules, hypotheses, theories, postulates, assumptions, empirical, experimental, analysis, synthesis, inferences, validations, generalization, particularization, and other technical terms. Regarding the above list of concepts, needed for the theoretical method to understand problems, we observe that many engineering courses, especially core courses, do not train students to master the basics of the scientific method.

As an example of this deficiency take the observation concept. Instead of training engineers to observe the real world directly and the working of nature, we observe that most engineering courses substitute the observation of the real nature and engineering systems by reading about observations. This means that engineers are used to obtain their information about engineering from reading books or listening to lectures. Similarly, engineers are not trained to understand the differences between laws, principles, hypothesis, and assumptions and how to use these properly in formulating and solving engineering problems.

In this respect the theoretical methods must be reinforced in engineering education. In this direction, engineers must be able, when facing problems, to examine the associated phenomena and to isolate the main features of problem under investigation. They should be able to model the problem using the laws of nature. Engineers should be able to classify the laws into two broad categories of fundamental laws and restricted laws.

Fundamental laws are those laws that express relations between physical quantities, which are independent of the specific properties of the medium, material and objects. Restricted laws are those laws that explain the behavior and properties of objects, material or a medium for a specific problem. Restricted laws depend on a specific engineering discipline such as electrical, chemical, biomedical, aeronautical or mechanical disciplines. Engineering students should be trained to know the conditions required to use laws. They should be trained to understand the differences between laws, principles, hypothesis and assumptions.

The above mentioned skills will help to create a suitable environment for the creative and critical thinking. They must be able to validate theories, results, and assumptions theoretically, experimentally and computationally. Students should be trained to see problems as deterministic or as probabilistic description of real situations.

Engineers should be trained to understand that many engineering problems can be described by a number of variables and the equations relating these variables are not enough to determine these variables uniquely. This shows the important role of engineers in selecting some variables to have a solvable set of equations. Also, engineers should be trained to know that for many engineering problems there in no single solution and they should be trained to use proper methods to select one solution from a set of solutions.

4.2 Problem Formulation Phase

In this phase, the theoretical background will be fruitful in helping engineers to formulate problems properly and to understand the limitations and conditions for problem formulation. The theoretical, the experimental and the computational methods should be combined to validate many steps in problem formulation. System theory is a recommended tool to model different engineering systems and to mathematically formulate the associated problems. The systems concept can be of great help to observe the problem from different aspects and add to it other interacting effects using the system structure, subsystems, feedback links, and the number of inputs and outputs to the system components.

Also, systems approach will help to isolate aspects and features relevant to a given problem to study its influence. Other aspects, such as hardware in the loop, social influences, human factors, economical factors can be added to see a more global picture of the problem within its real environment. Concepts of dynamics, equilibrium, open systems, closed systems, networking of systems, interaction, response, response time, delay, loops, nonlinear effects and boundary are very fruitful in this respect. The systems concepts can be used to formulate the problem using control terminology. Engineers should be trained to use state and control variables to model problems in a form of equations and boundary/initial conditions as well as to include the parameters that affect the solution of the problem. It is necessary to stress that the division of variables into state and control is arbitrary.

Students should be aware of the fact that the number of variables are usually larger than the number of equations and they should be trained to formulate a quantitative measure to help them in selecting the variables needed to close the set of equations. Validation is a very important concept and, in the formulation phase, students should be trained to validate each step theoretically, experimentally and computationally.

The role of mathematics is essential in this phase. Mathematics is the quantitative language of science and engineering. The quantities expressed mathematically must be of a measurable nature so that the engineers can manipulate these quantities, in the analysis and the design, meaningfully. Hence mathematics should be taught to engineers as an integral part of engineering curriculum and not as an isolated field of science.

Mathematics of engineering education must be of a nature close to the nature of engineering subjects and should be suitable for the modeling, the analysis and the design of the engineering systems. The physics concepts and the definitions must be used clearly in the modeling phase of the problems. Students should be trained to formulate, explain, and interpret engineering results by utilizing fundamental concepts and definitions of mathematics and physics. To achieve this, the skills of selecting the suitable laws and transforming it to equations should be sharpened.

4.3 Problem Solution Phase

From the previous two steps, the engineers will have a set of equations, concepts, laws, hypothesis, conditions and assumptions that model the problem at hand. The theoretical, the analytical, the experimental and the computational methods will be combined to investigate the possible solutions of the problem. Computer simulation will be used with the visualization techniques to study the various solutions. Initial conditions, assumptions, hypotheses, parameters, and problem conditions all can be changed to study its effects on the behavior of the solution. The hardware in the loop concept can be used to model an element or a component of unknown mathematical formula. Here the response or the behavior of the element is included in the model as an experimental model connected to other elements through input, output and computer data link.

In this phase, students should be trained to use iterative cycle, to repeat the process of problem formulation and solution many times, to study the effects of changing conditions, assumptions and parameters. The block diagram in Fig. 2 represents this cycle. Through this cycle the engineer should be trained to use relevant theoretical concepts to verify his model and chose the suitable parameters and conditions to obtain a best solution. The meaning of laws, assumptions, state variables, control variables, conditions, parameters, validation, experiment, model, and other concepts should be enhanced through this learning process. The mental association of mathematical entity, expressions or derivatives, to the engineering concepts will have a concrete engineering and physical relevance in this iterative learning process.

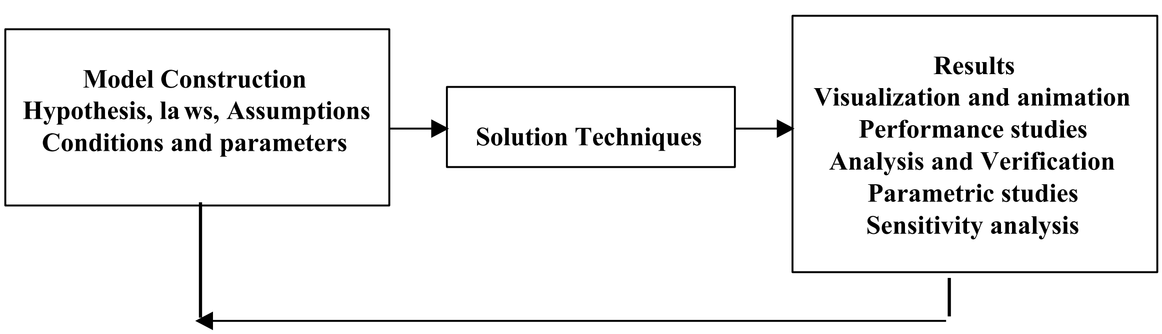

**Figure 2. Modeling, solutions and simulation cycle.**

Teamwork will be enhanced and reinforced in this phase. Students should learn to divide the work, and use members' different specialties to solve the problem. The coordination, and feedback skills, to correct errors and mistakes, will be enhanced using small group communication for problem solving. All these skills must be sharpened during this phase.

4.4 Presentation of Results Phase

A successful engineer must be able to communicate, present and visualize her/his results and findings in a clear, simple comprehensive way. Training engineers for presentation and efficient communication is an integral part in this phase. Engineers should be trained to use the information technology, networking, Internet, audio-visual and computer technologies as a part of their class work.

5. Curriculum Development

Our ultimate goal is to produce an engineer that resembles an information processor with enhanced human natural intelligence. This means that an engineer with the skills to: 1) receive or collect information, 2) select needed and relevant information, 3) reduce a huge amount of information, 4) diffuse information from different resources, 5) process information to reach conclusions. Information may come from any engineering discipline (reports, papers, books, or any information storage medium) or from the direct contact with the real world. An engineer should be able to use the fundamental tools of the scientific methods to process information and to reach results, and conclusions.

Based on the above the following core courses are suggested for all engineers before specializing in a specific area.

***Fundamentals of Engineering Sciences:*** This course should cover the unifying concepts like rate of change, flow, flux, field, process, system, force, pressure, voltage, potential, energy, stresses, strains, etc. Also, it covers the main engineering and physical principles. Examples are conservation principles, continuity principle, design principles, etc. This course reinforces the understanding of these concepts and the laws by using application from different engineering fields. Examples are fluid mechanics, aerodynamics, thermodynamics, electrodynamics, elasticity, stress analysis, chemical processes, plasticity, electricity, etc.

***Laws of Nature and Nature of Laws:*** This course should cover the meaning, classification, usage and application of laws, hypotheses, postulates, rules and principles. The division of laws into fundamental and restricted laws is of crucial importance. The course should include the fundamental laws of physics, chemistry, biology, ecology, and other scientific fields. The course should examples to illustrate the roles of laws and rules in science, engineering and technology.

***Data, Information and Knowledge:*** The goal of this course is to change students' skills from the skills related to information storage, to the skills related to information processing. Engineers should be able to differentiate between data, information and knowledge. Also, they should be able to know the differences between science, engineering and technology in their engineering disciplines. In this course, students should be trained to sharpen their skills to define, collect, classify, and fuse information. They should be able to differentiate between the relevant and the irrelevant. Information includes the properties and behavior of materials, objects, systems, devices, and equipment. In addition to that, students should be aware of the interplay between the function and structure of objects and materials of nature. The course should enhance the students' skills to describe the nature and processes quantitatively and to train students to classify various engineering fields of study according to the basics of each engineering discipline. Information processing is another focus of this course. Processing information include reduction, diffusion, induction, deduction, abstraction, theorizing, posing hypotheses and simplification. Presentation and communication is an integral part of this course. Students should benefit from the class activities to increase their communication skills.

***General Systems Theory:*** The goal of this course is to train students to understand problems and phenomena using system concepts. Students should be able to define a system, a subsystem, components, links, feedback, interaction, state variables control variable, measurable variable, boundaries, and parameters. Also, They should be able to use the concept of open and closed system and to describe and assign factors that show the influence of environment through boundaries. In addition to describing the effects of initial and boundary conditions on behavior, students should be able to explain the importance of changing the solution (bifurcation) and sensitivity to initial conditions and its relation to nonlinearity and chaos.

***Modeling:*** The goal of this course is to train students to model different systems using fundamental concepts and methods of modeling. The course should train students to use laws to express the model in a mathematical form. Student should be able to design an experiment, to model components that are difficult to model mathematically, and they should be able to validate the model theoretically, computationally and experimentally. Applied examples in this course should cover as many engineering disciplines as possible.

***Computer Simulation:*** The goal of this course is to train students to solve a problems using the available computer software. In addition to using canned computer software, students should be trained to write algorithms, computer codes and programs to solve model problems.

***Experiment Design and measurement:*** This course should to train engineering students to design an experiment, to measure physical quantities for modeling and to validate results of computer simulation.

***Engineering Mathematics and Physics:*** Mathematics and physics are indispensable to transform laws into equations. This course emphasizes the use of mathematics and physics in modeling. In this regard, algebra, calculus, linear algebra and differential equations texts should be written and taught with engineering applications in mind. Mathematics and physics is the language needed to express many engineering concepts and models. The content of this course should contain examples from different engineering disciplines. Association between mathematical expressions and physical/engineering concepts must be stressed in this course. Cognitive science and the learning theories must be consulted in writing this course.

6. The Total Lab Structure and Implementation

The above ideas can be implemented in the learning/teaching environment of many engineering courses. The class setting for total lab consists of computer lab connected to experimental facilities as seen in figure 3.

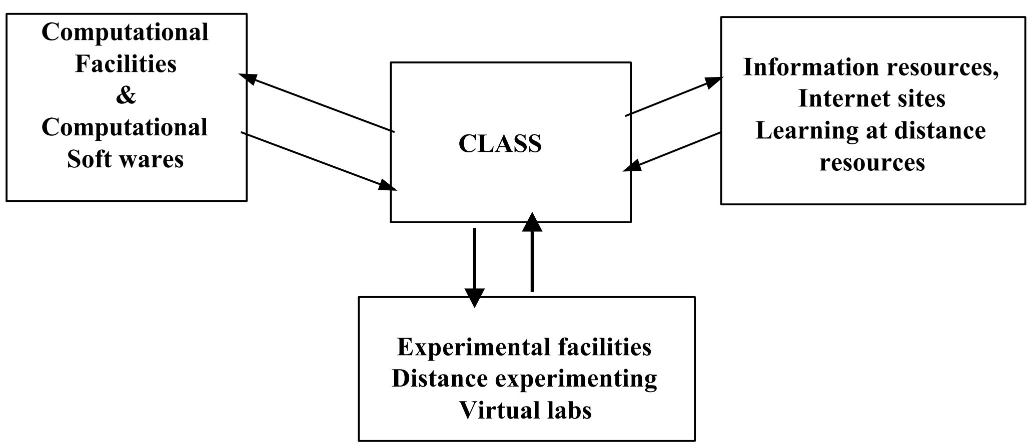


***Figure 3. Total Lab Setting.***

Implementing the total lab concept requires coordination between experimental labs, computer facilities and class activities. Activities include mastering the basics of the theoretical method, collecting and processing information, and presenting results. The class material or the suitable texts will depend on the engineering field. In the computer lab, students should be trained to use computers to manipulate information. Experimental labs should be used to train students to design experiments and to write experimental procedures to run an experiment. Instruction techniques should utilize the findings and discoveries of cognitive science, psychology and the theories of learning. Evaluation methods must employ different formats (interviews, questions, tests, exams, quizzes, oral presentation, etc.) to express quantitative measures that reflect the degree of achieving objectives. Evaluation should supply the instructors with the corrective measures to change the material in the lab and to remedy the deficit in instruction techniques employed. Learning at distance, doing experiments at distance, or virtual labs, and using a computer network will facilitate using equipment and devices from other universities and centers across the country.

## 7. Multidisciplinary Applications

Many engineering disciplines can use the total lab concept in their curriculum. Courses in fluid mechanics, structural mechanics, electrical circuits, chemical processes, aerodynamics, flight mechanics, thermodynamics, and systems dynamics can be rewritten to be suitable for the total lab concept. Biology and other medical subjects can use the total lab concept in their scientific field. This concept can be extended to social studies. Sociological, economical and historical fields of humanities can utilize the basic formulation and concepts of the total lab concept to deal and tackle problems in these subjects. Social engineering is another example of using the unified methodology[20].

## 8. The Tasks Required for the Integration

Referring to figure 1, integrating the technical dimension requires the following tasks: 1) Transforming the desired goals to specific skills and abilities, 2) Using the above skills to develop the curriculum, 3) Use the total lab concept to write the courses, for the foundation phase, for all engineering undergraduates, 4) Designing the identification process, 5) Designing the automated evaluation procedure, and 5) Assigning the roles of the elements of the controller (instructors, administrators, students).

## 9. Expectations and Obstacles

It is expected that applying the above ideas will produce engineers with capabilities, skills and tools that help the to tackle different engineering problems. Systems approach and modeling methodology will enable engineers to formulate and solve problems of multidisciplinary nature. The flexibility of dealing with different problems is based on a deep understanding of the concept of laws (fundamental and restricted) and using these laws to transform problem into equations and statements. Computational methods, computer technology and visualization techniques will help engineers to animate and to visualize solutions for different situations and conditions using simulation technology. Skills of experiment design will be of great importance in producing engineers able to measure, test and validate their findings. All these are fertile areas of critical thinking, creative thinking and problem solving.

Despite that, there will be many obstacles facing implanting the total lab concept. The main one is the cost of this reformation. Many universities and colleges do not have the experimental facilities that can be used to teach most of the engineering courses that focus on combining theory, experiment and computer in a unifying approach. Another obstacle is the availability of instructors who are willing to apply this concept in classrooms and labs. Other obstacles include writing courses, class materials and lab materials that apply the unified concept. In addition to that developing suitable methods to measure the performance of students' progress is a major issue. Methods of writing the tests, the exams and the homework, consistent with the objectives of the courses, for evaluation procedures should be addressed.

## 10. Conclusions

This paper is the first phase of an ambitious project that intends to change the way of conducting teaching, research and research training for undergraduate students of engineering and science. The ultimate goal of the paper is the curriculum development of engineering education to train students to use the basic tools of research as an integrated interactive tool to formulate and solve engineering problems. Engineering education for the next generation should direct students to master the basics of the scientific method in an integrated way. A consequence of that is the restructure of engineering curriculum to reflect this view. The paper addresses the philosophy of the total lab concept and illustrates its application. In the first part of the paper, the importance of reform of engineering curriculum to unify the technical dimensions is stressed. The second part treats the application of the total lab concept to unify the technical dimension of engineering education. In the third part different issues regarding the curriculum are presented. This includes the main components of curriculum, goals of engineering education, skills required for engineers of the next generation, curriculum development, implementation and multidisciplinary trend. The fourth part discusses the expectations and obstacles facing this project. A detailed application example, from the fields of thermal-fluid science and structural mechanics, will be given in another paper to illustrate the application of the total lab concept.

## Bibliography


1. Engineering Your Future, Great Lakes press, Inc., MO, 1999.
2. M. David Burghardt , ***Introduction to the engineering profession***, Harper Collins College Publishers, Second Edition, NY, 1995.
3. Phillip C. Wankat and Frank S. Oreovicz , ***Teaching Engineering***, McGraw-Hill, Inc., NY, 1993.
4. B. C. Blake-Coleman, The development of higher education for engineering in the 21st century, Measurement + Control Journal, pp. 143-145, Vol. 28, June 1995.
5. Bob Whelan, Bridging the innovation gap- a challenge you can't ignore, Measurement + Control Journal, p. 146, Vol. 28, June 1995.
6. J. D. Kuehler, Setting an Example for the Class of 2000, J. of Mechanical Engineering, pp. 56-57, February 1992.
7. Nathan H. Hurt, Engineering as Exploration, J. of Mechanical Engineering, p. 57, February 1992.
8. E. Alpay, Some Psychological Theories in Engineering Education, J. Chemical Engineering Education, pp.

212-219, Summer 2001.

9. Wayne Clough, The Future of Engineering Education http:// www.gtalumni.org/news/magazine/win00/future.html
10. PRISM online- March 2000-Re-Engineering in Germany.
11. Ben Erwin, Technology, Engineering and Education, http://www.cisp.org/imp/july_2000/
12. Six Sigma Strategies: creating Excellence in the workplace, http://www.qualitydigest.com/dec97
13. Sandra A. Howard, Guiding Collaborative Teamwork in The Classroom, http://cte.uncwil.edu/articles/howard/
14. Proposal to NSF for a National Engineering Coalition, 1990.
15. Dennis S. Bernstein, A Student's Guide to Research, IEEE Control Systems, pp. 102-108, February 1999.
16. Harvey Brooks, What is the national agenda for science, and how did it come about, American Scientist, Vol. 75, pp. 511-517, September-October 1987.
17. Kenneth C. Green. A Profile of Undergraduates in the Sciences, American Scientist, Vol. 77, pp. 475-480, September-October 1989.
18. How Do You Measure Success, ASEE Professional Books, 1998.
19. A. K. Mazher, ***The Total Lab Concept***: *An Integrated Approach to Unify the Technical Dimension of Engineering Education*, AIAA paper 2002-1053, 40th AIAA Aerospace Sciences Meeting & Exhibit, 14-17 Jan 2002, Reno, Nevada.
20. A. K. Mazher, ***Toward A Unified Approach to Modeling and Computer Simulation of Social Systems***, Part I: Methodology of Model Construction, a ***refereed paper*** , workshop on norms and institutions in multi-agent, Barcelona, Spain, June3-4, 2000. (**http://ccs.mit.edu/dell /aa2000/paper1.pdf)**

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