The Social Dimension of Engineering Education

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Abstract

Technological advances have an enormous impact on our life and its effects on society, environment and human values are evident everywhere. The engineering is no longer an isolated field of human activities and the future role of engineering demands that social, ethical and cultural aspects should be added to the technical dimension of engineering education. The next generation of engineers should have deeper concepts, wider views, more skills, and integrated tools to meet the challenges of the expanding spheres of knowledge and the challenges of globalization. This can be achieved through engineering education. Academic, industrial, and social institutions need to be restructured in order to meet today's competitive pressure and future challenges. Integrating the social dimension in the curriculum is one step. The other step is to train engineers to understand and analyze the social problems and issues using engineering tools of research. This will help to have deeper, wider and clearer picture of the social phenomena. In addition to that, enhancing the engineers' abilities in dealing with social issues will help to isolate the objective from the subjective and the relevant from the irrelevant. Up till now the engineering education has focused on the technical dimension and neglected the social dimension. This paper suggests a change of the engineering curriculum to include the social dimension. A unifying approach is proposed to implement the social studies in the engineering curriculum. The new course is called the social engineering. The goal of this program is to construct a unified approach to understand, formulate, model, simulate and solve many social problems. The suggested approach utilizes control engineering methodology and applies it to the social phenomena. The main hypothesis is that control engineering concepts and methods, when extended and applied properly to the social sciences, will lead to new insights to the social problems and their solutions.

1. Introduction

The philosophy of education has changed from the past to the present and will change in the future. The future of higher education, for the engineers in the 21st 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 this area of education. The development of higher education for the engineers in this country will undoubtedly include the need to respond to the changing nature of engineering itself. There are many factors in the world today that will shape the future of engineering education. Engineering is no longer an isolated field of activity in our society and the engineering education is changing reflecting a greater concern about the social, the political, the economic and the financial issues. A comprehensive picture for the future of engineering education must take these factors into consideration.

Assessment of engineering education in the beginning of 21st century requires reviewing the philosophy of the engineering education. This revision should include the main dimensions of engineering education, which are the technical dimension, the engineering profession practices dimension and the social dimension. The revision must suggest an integrating approach to implement the three dimensions in the engineering curriculum.

Traditionally, the engineering curriculum focuses on the analysis of processes and designing of systems, components, and devices that can be used to improve the working of existing processes or invent new artifacts[1,2]. The engineering programs concentrate on creating engineers with technical specialization, without focusing on the social consequences of engineering and technology[3]. 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 global market, multinational and transnational corporation has its own effects. Technological changes and challenges help emerging a new competition in the world job market. 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.

Technology has prompted most of changes in our society and will play an even larger role in the future. Globalization, internationalization of research, multicultural engineering teams and diversity of cultures all these influences the future programs of engineering education. The engineering workplace will benefit from the infusion of people with different backgrounds.

Technophobia has become an open issue. Many people see rapidly changing technologies and more complex world as frightening and deplorable. Our society is turned into a new machine where human spirit is suppressed. Changing in environment and society is happening rapidly. The impact of technology imbalances the human values to favor the materialistic values and individualism. This is seen in the huge varieties of industrial products that are produced to create and satisfy the never-ending human desires. Also, multinational corporations, and big companies focus on material profits and emphasizing the market values not human values.

Limitations of the natural resources (food, water and energy) and pollution are examples of the new challenges facing the engineers. In addition to that, harmful byproducts of technology (e.g. nuclear wastes, radiation, etc.) and its effects on health, human values, society and environment

must attract the attention of anyone concerned about the engineering education. Future engineers must be prepared to use technology to solve problems resulting from the limitation in the earth' natural resources, scarce of water and energy, and the resulting crises. The increasing demand on food, for increasing population on our earth, needs special use of technology to produce food for poor countries.

Education is indispensable arm for defending the social order. Society needs people who are educated as engineers to assist in the governance of the technologically complex systems. This requires that engineers become more socially and politically aware and active. Engineers should be aware of this situation and should be prepared to understand the global picture of the influences of science and technology. Engineering education, multinational/transnational corporations, economic and political systems are linked in the present day world. Engineering curriculum is related to the science policy of the countries where the political and the economical systems of the countries influence the education in turn.

To prepare engineers for the expanding market of globalization, the engineering education must be changed. The change should widen and deepen the understanding of engineers to the impact of science, engineering and technology on society. This requires a new approach to study the social issues from the engineering perspective. Improving the engineering education system is suggested by integrating the technical dimension, the social dimension and the engineering practices dimension as an interactive feedback dynamic system. This improvement should produce the engineers of the future without prolonging the time for graduation.

2. The Social Dimension of Engineering Education

The social dimension of engineering education deals with the issues that relate engineering to human life, human health, social dysfunction, human rights, and cultural issues. Engineering education should prepare engineers to deal with this dimension. An engineering treatment of the social problems will reduce many of the controversial issues and isolate the roots of many issues. These roots can be explained using the scientific concepts of postulates, hypotheses and assumptions. Engineering studies of a society is suggested through introducing a new field of the social engineering. Engineering methods can help to study the social phenomena in a systematic way and to investigate the impact of globalization on many aspects of human life. Training engineers to apply the scientific methods on social issues will help them to isolate the objective from subjective views. The total lab concept[4] was suggested as unifying scheme to restructure the technical dimension of engineering education. The same concept can be used as a unifying tool to integrate the social dimension and the technical dimension of engineering education.

A social phenomenon is treated as a control system. A social system is composed of subsystems where each subsystem is a combination of basic elements. The basic element is the human being. The structure of the social system will follow the construction concepts of the engineering, the physics, the chemistry and the biology. Social dynamics is described using qualitative and

quantitative descriptions. This description is based on using the social laws to formulate the problems and a set of rules that describe the social behavior. The description is expressed in terms of state and control variables. State variables describe the state of the system and control variables are used to change the state of the system. Part I of this work outlines the control engineer view of the social sciences. The aim of this part is to extend and apply the methods and concepts of control engineering and dynamical systems to the social systems. Part II focuses on the modeling and mathematical formulation of the social systems. Part III discusses the difficulties of solution techniques and the problems of modeling and computer simulation of the social system behavior. Part IV gives examples, as case studies, of the social engineering program and discusses the correspondence of concepts between engineering and the social sciences.

3. Social Engineering

In the last decade many research efforts have been directed to treating the social phenomena by employing many ideas and tools from artificial intelligence (AI), cellular automata (CA) and other fields[5-19]. This activity produced many concepts and definitions like artificial societies, multi-agents system model, social simulation, emergence theory, connectionist theory[5] and others. Examples of social modeling are the academic science structure[6], marriage system[18], segregation problems, socio-economic phenomena[8], and other studies[5,7,9-17,19]. Two main phases are followed to investigate these problems. In the first phase the problem and modeling concepts are used to formulate a model of the social problem. In the second phase simulation tools are used to study the model behavior. Reviewing the advances in this field, the following question emerges: is there a unified approach to tackle the social phenomena and formulate the diverse social problems? The program of the social engineering is one answer.

The social engineering is based on the assumption that the social phenomena are similar conceptually to the physical and the engineering phenomena. The difference lies in the way of describing the social structure and the laws that describe the social phenomena. To establish a field of social engineering, the following steps are proposed 1) Model the social phenomena as a system, 2) Assume that a social system works as interaction of basic subsystems, 3) Define the individuals as the basic elements of the subsystems. 4) Describe the behavior of the social element qualitatively and quantitatively, 5) Discover or postulate the laws and constraints that can be used to describe the dynamics of the individuals, groups of individuals, subsystems, systems and social networks, 6) Check the consistency, independence and completeness of the assumed postulates, 7) Verify the validity of the social local laws on experimental basis, 8) Employ the laws and the rules to study the behavior of interacting systems using ideas from systems engineering, control engineering and dynamic systems, 9) Investigate a subsystem behavior and proceed by increasing the number of interacting subsystems. 10) Study the effects of time delay between actions of social elements, 11) Postulate the rules that individuals use for interpretations of social signals, 12) Postulate the rules of group, or individuals, reactions to a social situation, 13) Study the changes in the local laws and the rules of interpretation as a result

of the degree of education, the level of learning and experience, and 14) Study the effects of the social networks on element action and the state of the system.

The social engineers will observe the social phenomena, design controlled experiments to focus on certain aspects, develop instruments to measure specific quantities, formulate hypotheses, test the hypotheses, form theories, verify/ falsify theories and formulate mathematical constructs to quantify the phenomenon. Two disciplines of study are combined to achieve the above objectives. These are the disciplines of the engineering and the social sciences. The concept of quantification used in engineering is introduced in the social context, and the foundations of engineering sciences and the social sciences are combined to construct the foundation of the social engineering. The engineering principles and mathematics tools are extended to study the social phenomena.

Based on the above, the problem of quantification of the social phenomena may be dealt with by modifying the social definitions and concepts to be measurable. These definitions and concepts describe the structure, the function and the laws of the social phenomena. We suggest borrowing definitions and concepts from mathematics, physics and engineering to reformulate the definitions and concepts of the social phenomena. First, the engineering concepts and methods to formulate and represent the social phenomena mathematically (Laws, constraints, equations, initial and boundary conditions and performance index) will be employed. Second, the difficulties of modeling and the problems of solution techniques will be discussed. Finally, case studies will be presented to show the feasibility of computer techniques to simulate social phenomena.

4. Towards a Program of Social Engineering

This paper suggests a general framework to establish the theoretical foundation of the social engineering. One objective of the social engineering program is to extend the methodology of mathematics, physics, and control engineering to formulate and study the social phenomena[20-34]. Another objective is to reformulate some concepts and definitions of mathematics, physics, dynamical system and control engineering to fit the social sciences. Viewing the social sciences from this perspective can lead to a unified approach to investigate the social phenomena and to implement solutions to social problems. This would help to have a global view of certain social processes and tackle the social problems as a dynamic system with multi-input, multi-output in a systematic way. The social phenomena are created by the behavior of individuals or groups and their interaction with other individuals and groups. Individuals are men, women and children. Examples of groups are families, societies, countries, states, organization, parties, banks, companies, armies or any group of people working or living together to achieve certain goals. The ultimate goal is to employ the scientific methods, the mathematical formulation and the computer techniques to quantify and solve social problems.

4.1 Objectives of the Social Engineering

Construct the foundations of the social engineering on a basis similar to the basis of control engineering. That means to describe, quantify, predict and control the social behavior similar to systems engineering way. This includes modeling, performance analysis, and stability studies of the social phenomena. This could be done by applying the main concepts and tools of engineering, after modifying and extending it to the social elements.

4.2 Assumptions of the Social Engineering

The social sciences study the social phenomena[35-37] and the basic element of the social phenomena is the human being. Social units are formed from the basic elements through their social activities. Examples of the social units are groups, parties, families, organizations, banks, companies and teams. The social systems and subsystems are combinations of basic units and social units. The social phenomena are the result of interaction between units within a social environment. Interactions that occur between humans, ideas, behavior, things and the environment follow certain laws and rules. We assume that all these social elements (individuals and groups) are considered as dynamic control systems. The social phenomena can be described, explained, controlled and predicted as results of interactions between many control systems. The social engineering is the study of the dynamics of the interaction of many social systems and its different aspects.

5. The Methodology

To lay the foundation of the social engineering, we will generalize the framework and tools of control engineering and apply it to the social systems. This will be done in following the three steps:

Step I: Borrowing some definitions and concepts from control engineering,
Step II: Transforming engineering concepts and definitions to social engineering,
Step III: Applying engineering principles to the social systems.

5.1 Step I: Definitions and Concepts from Control Engineering

A system is defined as a collection of interacting elements. These elements are composed of certain combination of electric, mechanical, hydraulic, thermal and pneumatic components. Each element has input and output and performs a specific function. A system is constructed from many elements to achieve assigned goals. The state variables and the control variables determine the state of the system at any time through a feedback mechanism. The control variables are selected to change the state of the system in order to achieve the required performance. The dynamics of the system is described by system of equations. These equations are obtained by applying the laws of nature to the system model. There are constraints that limit the values of the

control and state variables. To solve the mathematical equations and constraints, the control variables must be specified. Also, initial and boundary conditions are required. The control variables are computed to maximize or minimize an assigned performance index. The initial and boundary conditions are taken from the physics of the problem[20-26].

5.2 Step II: Transition from Engineering to Social Engineering

Going from an engineering system to a social system is the most difficult step. The social sciences study many social phenomena where the human beings, as individuals or groups, are the main active elements. Structure and function of social institutions, history and evolution of social structure and functions, mind, intelligence, learning, social behavior, beliefs, religions, economic systems, marriage system, etc. all are active research areas in the social sciences. The engineering ideas that may be applied to the social system are the concepts of laws, state and control variables, performance indices, feedback, networking, field, processes, dynamics and constraints. There are other concepts that will be added later.

5.2.1 Foundation of Social Engineering

To employ the ideas and concepts outlined above, and applying it to the social phenomena, we accept the following hypotheses, as the foundations of the social engineering.

H1:Structure Hypothesis
We will construct the social system following structure ideas from chemistry, physics, biology, systems engineering and mathematics.

In physics and chemistry matter can be described in macro or micro levels. In a macro model a matter is an aggregate of atoms and molecules. On a lower scale level, a micro model, it is composed of electrons, neutrons and protons. In a subatomic level, a model consists of subatomic particles or the smallest defined element 'quarks'. Statistical physics deals with microstructure while phenomenal physics deals with macro structure. In biology, an organism is composed of cells. Cells are basic units in macro level. An engineering system is composed of elements and subsystems[25, 26.] In mathematics the axiomatic or formal system construct the whole mathematics based on a certain number of postulates. Examples are number theory, linear algebra, algebra, Euclidean and non-Euclidean geometry. For a well-defined mathematical discipline, the main postulates must satisfy the consistency, independence and completeness conditions (See pp. 445-454 reference 29, pp. 214-215 reference 31, and p. 155 reference 33).

We will assume that the structure of social systems follows the same pattern of structure in physics, chemistry, biology and mathematics. The main component of the structure of the social system is the individual. Higher levels units or subsystems are constructed from combination of basic elements. There are rules that control the combination. Elements, units, subsystems and systems give the hierarchy of the structure. Examples are families, tribes, cults, banks, teams,

companies, institutions, and organizations.

There are two classes of structure: 1) Systems and subsystems structures, as outlined above, and it can be represented by a block diagram. 2) Communication structure where the working of units of a specific social system depends on communication, interpretation of languages, gaining energies, forming alliances with other elements and systems. These communication links form the social networks and can be represented by a mathematical graph. Social dynamics is the results of interaction between social systems and social networks. There are rules and laws for the formation of system structures as well as rules and laws that form communication structures (social network).

H2: Functionality and Interaction Hypothesis

In chemistry there are laws that control interactions and are used to explain chemical changes and chemical processes. Similarly, in classical and statistical physics there are laws and rules that can be used to describe physical processes and explain physical changes. In engineering, there are laws that are used to formulate system dynamics. There are two categories of laws: universal laws and specific or restricted laws. Universal laws do not depend on the medium while specific laws depend on the medium. Also, in mathematics inference and logical rules or laws are used to deduce theorems from axioms and postulates.

A social phenomenon is a result of interaction (action, reaction, cooperation, conflict, etc.) of main social elements, each element is trying to achieve his/her goals within the given social environment. Each element must follow the rules of the game. Therefore, we assume that any social phenomenon follows a certain pattern. There are laws that govern this pattern. Some of these laws are known and others are not known. Some laws are universal, those which do not depend on a specific society, and other laws depend on the society (religion, values, and ideology). The results of interaction may change the local laws through learning and experience. Certain observed rules are 1) Not all elements have the same influence, 2) There is a feedback interaction between the elements of the system, 3) The state of each element is influenced by the state, control and the social network of other elements, 4) Goals of the elements are not consistent, these produce conflict of interest. Social interaction can be represented by a flow chart.

H3: Hypothesis of the Social Laws

Parallel to the laws in physics, chemistry, biology, and engineering, we assume that social phenomena are described by social laws. These laws may be known or not discovered yet. With known laws, we can study the social phenomena quantitatively and qualitatively. There are two categories of laws that control the dynamics of a social system. These are universal and local or specific laws.

Universal laws here mean universal from the point of view of a researcher who can see all social groups follow, aware or not, these laws. These laws do not depend on the properties,

characteristics, structure, function or situation (social conditions in space and time) of any social group. Examples of these laws are 1) The rate of social change is proportional to the changes of social forces, 2) The defeated follow the winner, 3) The social world is controlled by a small number of individuals and groups (singularities generate main ideas, rules, concepts, etc of the society), 4) The majority of people follow the social field (psychology of masses), 5) There is a force of attraction or repulsion between individuals and groups (personal chemistry). This force depends on common or conflicting interests, languages, habits, values, culture, etc. If the motives of an individual or group are stronger than his resistance (inertia), he will change his equilibrium conditions by moving to another state of mind, other ideas, other locations (immigration). There are three categories of universal laws. First, the laws that control the behavior of elements of a social system. Second, the laws that are essential to understand forming social networks. Third, the laws that are necessary for fruitful communication and interpretation.

Local laws here means that the laws of a certain group of people which depend on their history, geography, habits, language, beliefs and environment. Many individuals consider their laws as universal, while outsiders consider it as local, and they see their laws as universal. These specific laws are related to norms, values, and obligations of specific cultures. It changes with beliefs, education, immigration, and experiences. Examples of these local laws are, 1) Religion is a social force, 2) Religion is personal, 3) No relations between state and religion, 4) Science is the only source of knowledge, 5) Religion is a major source of knowledge, 6) The individual is more important than society, 7) Society is more important than individuals, 8) Man is better than woman, 9) Certain ethnic group is better than other ethnic groups, 10) The laws of interpretation of meaning, symbols, texts and signals in a given culture.

There are two categories of local laws. First, local laws that limit the behavior. Second the local laws that are necessary for communication and interpretation. It is noted that many groups and individuals try to make their local laws universal laws. They try to force others to follow and accept, if possible, their laws. This can be done through mass media, products, education, occupation of lands, books, banks, exports and imports, economy, armed forces and other means. History gives us many examples of the influence of countries and individuals over other countries and individuals. The transfer of ideas, concepts, cultures and the products of civilizations change the local laws.

Local laws are considered cultural constraints. In each society there are restrictions or constraints that limit the action and behavior of an individual or group. These may be in a form of written laws or unwritten (customs, habits, ethics and religious codes of conduct). We assume that we can discover these constraints and write them in a form of statements or rule of behavior. We call these “The Postulates” of the given society. We could write these postulate as a sequence of rules that can be programmed by a computer. These postulates limit actions and control the behavior, therefore we call them constraints. These constraints are characteristics of the social environment. It gives us an understanding of the cultural effects, historical or social memory influences, short and long memory effects, non-linearity, and sensitivity to certain conditions in

certain situations (chaotic behavior).

H4: Correspondence Hypothesis

In control engineering, sets of equations that describe the system behavior are obtained from applying the laws to the model. The model is specified through state and control variables. To solve the equations, initial and boundary conditions are needed. In the social engineering we have corresponding concepts to boundary conditions and initial conditions. These are social environment and social situation. The environment imposes its effects, through the social field, within a certain time interval, on the dynamics of the system by the selection of certain local laws. The situation is the starting condition that activates a social event; it is similar to the initial conditions of mathematical physics. It depends on the basic element capabilities of communication, interpretation and response to other element actions and depends too on the individual emotion, rationality, mood, education level and experience.

5.3 Step III: Applying Engineering Ideas to Social Systems

The proposal to engineer the social phenomena focuses on the following points: 1) Definitions and concepts of social engineering, 2) Social processes, 3) Social dynamics (block diagram and flow chart representation), and 4) Quantification of Social Sciences.

5.3.1. Definitions and Concepts

From an engineering point of view, we need to deal with the social phenomena as an engineering system. In this respect, we seek to quantify the social phenomena. Ideas, goals, interests, behavior, and actions need to be quantified. Not all aspects of social behavior can be quantified by the current state of knowledge and scientific procedure. Definitions and concept from mathematics, physics engineering will be formulated within the context of the social system.

The following definitions and concepts are taken from mathematics, in an effort to extend and apply them to the social phenomena: Axioms, postulates, formal system, independence, consistency, contradiction, completeness, necessary and sufficient, induction, deduction, inference, theorem, group, element, operation, linear, nonlinear, continuity and discontinuities.

The following definitions and concepts are borrowed from physics, in an effort to extend and apply them to the social phenomena: Phenomenological, statistical, force, inertia, energy, power, field, laws, principles, theory, hypothesis, stochastic (random), and deterministic.

The following definitions and concepts are taken from engineering in an effort to extend and apply them to the social phenomena: State variables, control variables, cycle, process, reversible and irreversible, equilibrium, modeling, simulation, degrees of freedom, discrete, continuum, system, representation of a system, inputs, outputs, dynamics of the system, laws, deterministic and random (stochastic) systems, analysis of the system behavior, response, performance,

stability, control, observable, controllability, sensitivity, random effects, measurements, performance index, and constraints.

5.3.2 Social Engineering Definitions and Concepts

We will adopt the following social engineering definitions and concepts: Social behavior, continuity and discontinuity of social behavior, non-linearity of the social behavior, chaotic or stochastic behavior, Social postulates (inconsistency, incomplete, dependent), formal system of social science, social processes, social change, social force, social energy, social field, social space, social distance, social laws or norms, social problems, social stagnant state, social equilibrium and stability, social inertia (the resistance to change the attitude, ideas, concepts), social system, dynamics of social systems, prediction of social phenomena, solvable/unsolvable social problems (no solution/many solutions), knowledge gap, equilibrium of social phenomena, irreversibility of social phenomena, stability of social phenomena, observability of social phenomena, measurability of social phenomena, social control, and controllability of social phenomena

Social Processes
Each social unit or element tries to be in her best energy state while maximizing her interest and minimizing possible losses. Low energy state is the state where the person does not resist previous ideas, concept, theories (laziness, sleeping, death, are stagnation state). One of the most fundamental concepts in the social phenomena is social change. Social change is produced in a society through social forces. There are many types of social forces. Individuals and groups influence society through social forces and social fields. A social element tries to achieve his interests in the society by exerting a control while following the rules of the game. The degree of success of each unit depends on his social power. Social power can be an accumulation of arms, wealth and knowledge. These three sources of power force many individuals and groups to unite together (allies) to strengthen their resources of power and achieve a compromised interest. Their interests are proportional to the power of each.

Social Dynamics
Social dynamics must follow certain laws. Social systems do not behave without restriction. Specific laws and rules, in the form of norms, values, commitments, obligations, rights, permission, responsibility, etc are imposed on the system. Dynamics differ according the nature of the laws and the rules that describe the system. There are two types of social systems, artificial and natural. Social system dynamics depends of the type of system used.

The behavior of an artificial society follows logical and rational rules. Individuals follow specific rules without thinking or interpreting implied social meaning of signals. The rules, laws, bylaws and constitutions are planned or artificial, i.e. set by the planers/programmer and not discovered from a real society. The designers, or the planners, of the social institution write rules or laws of the organizations, parties, banks, companies, etc. Rules are consistent, independent and

complete, i.e. sufficient to describe the assumed situation. There is no time difference between action and reaction of agents (no delay). All behave simultaneously. There are no memory effects of history or experience. Learning effects are negligible or slow (following the book).

Generally, natural societies do not follow the above artificial or planned rules and regulations. It is observed that not all individuals are rational or logical beings. Their behavior is a complex and dynamic mix of logical and emotional actions and reactions. Natural society is composed of individuals not all of them follow specific rules systematically. For many individuals, some rules are known in advance, some rules are ambiguous and some rules are multi-valued. In addition, individuals do not have enough rules to reach solid conclusions in every situation. That means that the number of rules is not sufficient to deal with a huge amount of data and to reach the needed information for decision making. Many individuals, in different situations, can not decide. Sometimes they change their minds, other times they act, and on other occasions they do not take any action. Also, individuals do not care about the consistency, independence and completeness of their rules. Logical inference, using rational rules, is not a characteristic of individuals. Artificial rules are not sufficient to explain the behavior of a real society. Individuals interpret things differently in different situations; their interpretation depends on their mood or mental state.

Effects of culture on local laws and norm can not be neglected. Also, education, experience, interpretation of laws and rules must be taken into consideration. As a system, there are laws and constraints of social element as well as rules and restriction of the institution or organization. Also, the goals of social units are not always the same. Goals, rules and norms of a system as a whole and its units are not necessarily consistent. Controls are employed to achieve goals or interests of elements. Sometimes goals of elements of society and the society itself are inconsistent or conflicting. Not all elements of the society are equal in their effects on the social dynamics. In general few persons have strong influence. Examples can be cited from banks, armies, companies, parties and families. Rules of communication and interpretations of language between different elements of the system must be considered. Each element has a partial knowledge about the goals and rules of actions of other elements and the entire system. Interpreting language, selecting specific meaning and action taken depend on understanding the meaning embedded in languages.

In natural societies people use different languages for communication. Natural languages are not exact and accurate like mathematical language. People select from a huge number of ideas some ones and interpret them to take actions. Many concepts and definitions that individuals use are not clear, definite and concise. Some words have many meanings, which depends on culture, experience, and level of education. Some statements are ambiguous and individuals interpret them differently. Interpretation of words, concepts and symbols depends on facts and theories that individuals develop and all these change with experience and learning. Also, an interpretation depends on the environment, situations and other individuals participating in the given situation. In general the behavior of the natural social element is nonlinear and sensitive to

the social situation. In addition it is adaptive, depends on memory, culture, media, education level and changes by learning and experience.

5.3.3. Quantification of Social Sciences

A social phenomenon is described using partial quantification and partial qualitative statements. The combination of theory and practical aspects is enhanced to simulate the behavior (qualitatively). The following are the suggested steps: 1) Study the behavior of a social system and seek quantified features, 2) Combine the quantitative and qualitative aspects, 3) Simulate behavioral changes by using a huge number of local laws, postulates and starting conditions (mood), 4) Use suitable tools to predict the different possible patterns of behavior (scenarios), 5) Use different methods to control and change behavior to improve performance, 6) Study the interactions of a group of people with other groups in a certain environment, 7) Use this study to see how each group behaves to achieve its goals, 8) Relate the finding and results, developed in this branch of engineering, to the theories developed in the different related fields of study.

6. Problem Formulation in Social Engineering

The formulation of the problem in the social engineering follows the following steps: 1) Define the number of systems, 2) Establish the social network, 3) Define the state variables that are related to the social phenomena, 4) Define control variables that are related to the social phenomena, 5) Define the system and identify inputs, outputs, 6) Apply the laws to obtain equations, if possible, 7) State the relevant constraints, norms or rules, 8) Specify the environment, 9) Specify the situation, 10) Specify the performance indices, 11) Employ the suitable techniques to find the evolution of state and control with time, and 12) Simulate the problem for different situations and different local rules.

7. Branches of Social Engineering

The main two areas of social engineering are theoretical and applied. The objectives of the theatrical studies are 1) Discover the laws and constraints (postulates) of a given social system model; 2) Discover and classify the laws according to certain criteria (universal and local), 3) Verify the validity of the constraints (postulates and hypotheses of the model), 4) Specify the existing conditions and the memory effects (culture & history), 5) Formulate the social problem using mathematics and assign the conditions and steps for correct formulation, 6) Develop methods and techniques to solve the social problem as formulated mathematically and 7) Develop tools to simulate the solution. Some examples of theoretical studies are 1) Classification of social engineering into macro and micro, 2) Structure of social networks and associated social fields, 3) Discovering the universal laws, 4) Finding the postulates of a certain society, and 5) Defining the interest.

The objective of the applied social engineering is to solve problems of societies using

engineering tools. The solution procedure follows these steps: 1) Define the interacting systems (micro or macro), 2) Define the state and control for each system, 3) Formulate the problem using control and systems methods, 4) Close the system of equations and constraints employing a performance index, 5) Transform the postulates into rules of action, 6) Study the effects of a social network on the control and states, 7) Simulate the behavior by the integration of multiple interacting software, 8) Study the observability, measurement, controllability, and stability of the state, and 9) Suggest solutions to improve performance.

Examples of suggested applications are: 1) Marriage and divorce problems, 2) Children education, 3) Distribution of wealth; 4) War studies, 5) United Nations resolutions, 6) Banks control of money flow; 7) Controlling oil price and 8) Companies and market control.

The following scientific areas are of great help to social engineering: Data fusion, neural network, artificial intelligence, fuzzy logic, graph theory, data mining, systems engineering, and theory of games.

8. Expectations and Obstacles

Systems approach and modeling methodology will enable engineers to formulate and solve problems of social 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 visualize solutions for different situations and conditions using simulation technology. Despite that, there will be many obstacles facing implementing the social engineering concept. These obstacles include finding and classifying the social laws, writing courses, class materials and lab materials that apply the unified concept. A lot of research is needed to study the whole spectrum of social phenomena and cast it in engineering terminology.

Future engineering education must implement an element in engineering curriculum to discuss social issues from engineering perspectives and focus on the role of engineers in solving part of the harmful side effects of using engineering products. The total lab concept[4] 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 with and tackle problems in these subjects[38]. Social engineering is proposed as a new field of engineering, which utilizes the control theory methodology[39].

9. Conclusions

Engineers have a special status in our age of technology and must be educated to solve new problems. Engineering must have a role to understand and solve the emerging social problems and clarify the controversial social issues. This paper discusses the social dimension of

engineering education and suggests a new course of the social engineering. The ultimate goal of the paper is the curriculum development of engineering education to integrate the social dimension and to train students to use the basic tools of research as an integrated interactive tool to formulate, analyze and address solutions to the social problems.

Engineering education for the next generation should direct students to master the basics of the scientific method in an integrated way to deal with engineering as well as social phenomena. Hence, it is necessary in the 21st century to widen and deepen the role of engineers in our society. A consequence of that is the restructure of engineering curricula to reflect this view. This paper suggests that engineering curriculum reform will help to create engineers able to deal with the problems associated with globalization.

The engineering field of modeling and simulation using computers has reached a level that convinces us to apply its techniques to social phenomena. Reviewing the results of that field encourage us to establish a program of social engineering. This requires combining the foundation of modeling and simulations in engineering fields and the foundations of social sciences and examining the possibilities so as to add a new field of social engineering to other fields of engineering. This paper outlines the general approach of the social engineering program.

The basic idea is that the study of social phenomena is similar conceptually to the studies of physical and engineering phenomena. Structure and laws are the unifying tools. The difference lies in the nature of laws that describe the phenomena. Studying different possibilities and influences of environment, culture, local laws, interoperation, delay, learning may help to discover many reasons of human conflicts and social problems. This will identify different areas as sources of social behavior and problems. Therefore, to establish the field of social engineering, the following scheme is proposed. 1) Model social phenomena as a system, 2) Assume that a social system works as interaction of subsystems. Each subsystem consists of basic elements, 3) The basic element is an individual, 4) Describe the behavior of this element qualitatively and quantitatively to represent the major behavior of a real social element, 5) Find or postulate the laws and constraints that specify the dynamics of the individuals, groups, subsystems, systems and social networks, 6) Check consistency, independence and completeness of postulates, 7) Verify the validity of the local laws on experimental bases, 8) Employ laws and rules to study the behavior of interacting systems using ideas from systems engineering, control engineering and dynamic systems, 9) Investigate one system behavior and proceed by increasing the number of interacting systems, 11) Study the effects of time delay between actions, 12) Vary rules of interpretations, 13) Vary rules of reaction to situation, 14) Vary the local laws according to a systematic pattern that follow education, level of learning and experience, 15) Study effects of social networks on action and state of the system.

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