STRUCTURE OF KNOWLEDGE FOR ENGINEERING CURRICULUM REDEVELOPMENT

by

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SUMMARY:
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KEYWORDS:
Education, Curriculum, Structure of Knowledge

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ABSTRACT

A model for upgrading engineering education and curriculum restructuring for the 21st Century is presented. The three dimensional model was developed to facilitate the changes required by the current engineering programs. The three dimensions of the model include the principal partners of society, the stages involved in model adoption, and specific goals required by the program. Included in the overall strategic plan is the development of the Structure Of Knowledge (SOK) for the courses within the engineering program. The SOK consist of the functional operations of the material, identification of the modes of inquiry, and identification of the tools that can be used to assist in obtaining a solution to a specific problem. Once the SOK for the courses of an engineering program can be developed, the curriculum can be changed. Without the essential elements of the material identified, there is no way a balanced curriculum can be developed for producing the professional engineer of the future.

PROBLEM IDENTIFICATION

If we expect to fill the future needs for more than 500,000 scientists and engineers (Booth, 1989), we must look beyond the traditional student population toward the large, untapped pool of non-conventional students. It is desirable to have all components of the population represented equally in the work force. Unfortunately, small ratios of non-conventional students often exist in the fields of Engineering, Mathematics, and Science (EMS). Non-conventional students are defined as (1) minority students, (2) female students, (3) adult students (age 25 and older) returning to school, and (4) students from small schools that lack the personnel and facilities necessary to properly train students prior to entering college. Recruiting non-conventional students into EMS programs is particularly critical in many southwestern schools, as these schools have a large number of non-conventional students in their region. Non-conventional students report feeling incapable of competing scholastically with 'traditional' students in EMS programs. Their poor preparation and lack of confidence cause the non-conventional students to choose the route of the community college as a starting place for their higher education. If the non-conventional students do enter EMS programs at major universities, many do not graduate because they do not fit into traditional programs. The present higher education system does not meet the needs of the non-conventional student. Part of the problem of obtaining and maintaining the non-conventional student in EMS programs may be caused by the fragmented instruction and lack of mentoring provided to students from unarticulated programs. In order for students to be eligible to enter and then graduate from EMS programs, they must have (1) the general academic skills required of all college students, (2) an understanding of a set of essential elements of knowledge required by specific disciplines, and (3) mastered the fundamental concepts associated with a particular discipline.
Another deficiency in science and engineering education today is the lack of student involvement in planning their course of study. More importantly, the student's creative ability to visualize a problem and solution is curtailed, which produces engineers that can calculate and compute, but cannot invent new technology. We feel that a mastery of the fundamental laws of EMS is a critical factor in preparing engineers who can produce new technology as well as calculate and compute. Also, sophisticated science laboratory experiences in undergraduate programs is often demanded by the industrial employers of our graduates. Employers expect engineering graduates to be able to use appropriate technology and to do original problem solving.

Collins (1990) states that when one considers trying to tackle the task of upgrading educational strategies they must realize that the process is continuous. In addition to being continuous, the process will require a tremendous amount of effort. If more effort is not invested in education soon, the United States will not remain in the economic forefront (Johnson et al., 1984). In the engineering discipline, two major issues have surfaced: the attraction and retention of students, especially from the "under-represented" groups. In order to attract and retain any student in an engineering program, the program must be precisely structured to the students interest and benefit. In most cases the problem lies within the curriculum, but more precisely the problem is with the course content (Van Valkenburg, 1990). Considering the scope of the problem, it is obvious that no single person can solve the entire problem, but a collection of dedicated people can change the system significantly.

To initiate the collection of people required to find a solution to the educational problems the Coalition for Upgrading Educational Strategies (CUES) was developed (Fedler and Hensley, 1990). The main purpose of CUES is to design and test innovative strategies to upgrade developmental and engineering education and lead in the renaissance of education that will guide the development of professional and technical education programs into and through the 21st century. Sometimes individualism, but more often distance between institutions has prevented the exchange and cooperative development of technological information. CUES is made up of numerous types of cooperating institutions that realize no single institution has all of the resources nor the expertise to meet every educational need. The coalition members are committed to collectively design, test, and implement specific strategies for improving engineering education.

If the proper or "best" education possible is to be provided, a structure of all of the essential elements for each discipline must be developed and made available to all faculty. It is believed that the educational deficiencies of current students are attributable to the fragmented educational efforts within our society. The coalition, which is composed of several different types of institutions, is dedicated to developing joint strategies that provide articulation of educational programs that include the basic understanding of the essential elements required for students to be placed immediately into the workforce. The cooperating institutions are committed to establishing collaborative arrangements that demonstrate successful strategies for preparing these professionals for a society demanding an increasingly sophisticated science that only comes from an elegantly educated population.
We are in the process of creating a model environment to encourage non-
conventional students to understand the essential elements of engineering,
science, mathematics and communication and to engage in original problem solving
at the freshman level. Once created, this pilot program should serve as a model
for changes to be made in programs at other colleges and universities. The team
feels that students understanding the structure of knowledge for disciplines
necessary to engineering and mastering the basic skills and essential elements
of the disciplines are critical components in teaching non-conventional students
the joy and satisfaction of becoming independent scholars.

**NEED FOR NEW MODEL**

**Background**

With the development of the essential elements of engineering knowledge, we can
provide our students with the excitement of an enhanced learning experience.
Basic principles of engineering are taught in core courses, but rarely are they
demonstrated as they apply to the real world problems, nor is it shown that many
of the laws are similar in function. When students are required to apply these
principles and use or develop instrumentation, a stronger understanding of those
principles results. Also, teaching by "doing" stimulates the students' creative
abilities producing engineers that can visualize new products and better use
available resources.

Understanding the essential elements of engineering knowledge plays a key role
in optimizing total educational and creative ingenuity. In fact, as Glasser
(1989) noted "we need to face the fact that quality is much more than memorizing
and parroting facts or answering academic questions, even hard ones that require
math and science, that are not related to recognizable, real world problems..."
The immediate need in engineering education is to develop courses that lead
students to a true understanding of the basic principles of engineering, math,
and science and how they apply to real world problems. Obviously, a well thought
out and complete study strategies that addresses fundamental EMS problems and
requires students to explain what and why they are doing a task as they do the
task, would be a very effective teaching tool.

**Curriculum Restructuring**

Revitalizing undergraduate engineering programs, more specifically the
curriculum, is recognized as a necessary step in order to properly prepare our
students for the 21st Century (Ernst, 1989; Fromm and Quinn, 1989; Van
Valkenburg, 1988; and Wenk, 1988). Some academicians go as far as to say that
the amount of material required by the engineering student of the future can only
be provided within a 5-year program (Cady et al., 1988 and Skoner and Jolongo,
1988) rather than the current 4-year program. Wenk (1988) states that the
paradoxes of today's society are that more information is required, but
unfortunately less understanding follows under the current system due to the time
constraints. This is a critical problem for all fields of science and
engineering as the amount of scientific information is doubling every 2.5 years
(Barlow, 1991). It is particularly troublesome for the undergraduate engineering
faculty as they must continuously scan an enormous variety of disciplines for the
purpose of incorporating relevant information into their professional knowledge
for specific engineering courses in specific fields. Agreeing with Van Valkenburg (1989) that "students taking a jammed-full course in a jammed-full curriculum may not learn any topic well," it points out that educators have somehow lost track of what is important in a given program. Wenk (1988) notes that the current curriculum is obsolete in that it primarily trains technicians rather than training true engineers. In fact, there is the need to develop a new master plan that does not try to teach every course an engineer could possibly need (Van Valkenburg, 1990).

Leadership for major advances in American higher education in the past have been provided by approximately 100 independently working prestigious institutions. These institutions have succeeded quite well in creating the most elegant education and sophisticated science that the world has ever seen. Operating on the simple principle of raising standards, these prestigious institutions select smaller percentages of the top students. It is a small wonder that they claim a large percentage of Nobel Laureates and captains of industry. They have created a "traditional student" college preparatory track that quickly ushers a conventionally prepared student into a quality professional program. This type of student quickly adapts to the rigors of the research-dominated institution and successfully completes the undergraduate requirements for a degree. Unfortunately, the majority of today's students do not fall into this traditional role and existing policies are not adequate in preparing the large number of science and engineering students demanded by our nation to keep it internationally competitive. Educational changes are necessary to prevent the shortage of students, and the authors believe that the leadership for the breakthroughs in education will come from the untypical study groups operating across disciplinary and institutional boundaries.

**THE BASIC MODEL**

Since the basic model may be viewed as such a radical change to current educational strategies in engineering education, it is necessary to identify the strategy in detail. We depend on two assumptions: first, a planned change is facilitated by drafting a strategy, and second, the strategic plan is essential to avoid fragmented and abortive efforts that vitiate the energies of on-going operations. Within the planned strategy, we must identify all the principal partners involved in the change and recognize that voluntary change occurs when the principals involved are aware of what the change involves when they accept the new strategy.

We began the planning activities with a model that shows the major development thrusts (Figure 1). This fundamental change in knowledge organization was developed to offer several significant advances in curriculum restructuring that could not be achieved with conventional texts, syllabi, and existing testing programs. Figure 1 shows the major components of the basic model and the strategic planning process required for its adoption into current programs. The three dimensions of the model include: (1) the principal partners of society involved in the planning process; (2) the specific goals; and (3) the developmental stages involved in model adoption.
Principal Partners

Strategic planning and identification of all the principal entities involved in the development of any major project was the first requirement. The five principal partners required for upgrading educational strategies are the University, State, Federal, Industrial, and Private sectors of society. The university sector includes students, faculty, and administrative officers, each fulfilling an important part of the overall structure of the model. The students, of course, are the purpose behind developing new strategies in education. Faculty, on the other hand, are the key players in developing, organizing and teaching new material. The administrative officers are vital in searching out potential resources and instituting the new plan.

The primary areas of support required to educate future scientists and engineers should be provided by the state and the private sectors of the partnership. The private sector includes individuals donating funds for educational purposes as well as independent and industrial Foundations. Federal support must not be excluded from the partnership, but this support may and is often shifted to the state level for distribution. In addition, the largest user of the end product of the educational system (industry) should provide a significant share of the support required by the system.

Developmental Stages

The second dimension of our model represents the "Developmental Stages" involved with education reform. Initially, the architect must carefully detail the master plan and find advocates who can logically convince the targeted constituencies of the benefits that will accrue to those individuals adopting the change. The advocates must next produce an awareness of the problem that exists. Once an awareness is made, it is recognized that a new solution must be developed and accepted by the constituencies. After the new model is accepted, it is relatively easy to gain adoption into current programs.

Goals

The overall strategic plan of our model is not complete without a set of goals to be accomplished. Our goals begin with determination of the essential elements for each course. These essential elements are required if we expect to develop the proper curriculum for the engineering discipline. In addition, the time required for the average student to properly learn each of the essential elements needs to be determined. The time element allows the instructor to plan each lesson with a high level of confidence and assures that all the essential material is covered. After the essential elements are defined and the time required to master the material is understood, a suitable curriculum can be produced for the academic program.

Our next step is to test the prototypes developed for each course and assure that all the essential elements have been defined. In addition, the delivery and receiving system strategies are to be analyzed. Even though delivery and receiving is a small part of the overall plan, it should be recognized as an important part and implemented within the program. With all the components of the initial system in place, the entire model must be evaluated and refinements made.
The final step of the plan is to transfer the technology.

Even though the overall plan appears simple, or even obvious, it must be noted that the first two goals will require several years to complete for each course within a discipline. Thus, the solution to the science and engineering curriculum development can’t be solved by a single individual, but a collective team from several disciplines.

**STRUCTURE OF KNOWLEDGE**

The functional Structure of Knowledge (SOK) is the conceptual model that integrates the activities of Project SUCCEED and sets it apart from other undergraduate curriculum and course development projects. SUCCEED is an acronym for Structuring Undergraduate Curriculum and Courses for Essential Educational Development. The idea of a functional structuring of knowledge for engineering is a major change in thinking about curriculum and course development. Project SUCCEED is derived from the general belief that undergraduate EMS curricula and courses must be revised to make them more efficient and responsive to our technological society. And, it is based on the assumption that the functional structure of knowledge is a prerequisite for making major improvements in the EMS undergraduate education.

The functional SOK should prove to be a very powerful conceptual tool for EMS curriculum redevelopment and course revision. Once the model of a discipline is shown and the theory for functionally structuring knowledge is explained, professionals acknowledge that the structure is obvious and that the theory is appropriate.

**Neo-Epistemologists View of SOK**

The work of the Engineering Educator is the creation, organization, and dissemination of knowledge. Their job is to discover new knowledge, to organize knowledge into easily accessible systems, and to teach students how to find and use available knowledge. Engineering and all other educators are faced with the problems of epistemology. In the understanding knowledge for engineering, we first must consider epistemological problems because, either consciously or subconsciously, they play a great part in curriculum restructuring.

The first task of the neo-epistemologists is to know who they are and where they stand in regard to theories of knowledge. This is particularly important for engineering educators in the latter part of the 20th Century for their effectiveness in organizing knowledge and in disseminating it will rest on how they view the nature of knowledge and their role in the education enterprise.

For neo-epistemologists the point of departure for the study of knowledge is new and radically different from classical epistemologists. Socrates, Plato, Aristotle, and subsequent academicians have started their theories of knowledge from the point of "subjective-rationalism." We start from the position of "collective-extantism." These starting points are polar opposites and while we may arrive at some of the same destinations our ways of knowing are vastly different.
"Subjective-rationalism" relies on the isolated individual's rational thinking to arrive at a solution to a problem. Classical epistemologists start with the assumption that each person must determine what they can know, how they can know it and what is "truth." "Subjective-rationalism" was the way the student in the Academe thought. It was a great advancement over the mysticism of the Orient, but it gravely limits what man can know as an individual. In a society that is now very interdependent, subjective-rationalism is important for the solution to many new and old problems, but it is a way of thinking that always starts the individual thinking at ground zero on every problem. This discounts the notion that humans can rely on other humans for answers to their problems. Most of our present problems have been solved by individuals who earlier discovered solutions to great questions about this world and its people. They bequeathed to us their solution.

"Collective-extantism" relies on the individual's selection of a generic problem-solving mechanism from disciplinary depositories of knowledge and then applying that knowledge to a practical problem in the real world. Neo-epistemologists start with the assumption of what man collectively knows. If a generic solution to a problem already exists there is no need for the individual to recreate the model. This model allows each person to build on what others have already discovered. We can learn how others have solved generic problems and use their methods. The neo-epistemologist like the classical epistemologist are concerned with "truth"-the validation of what man believes and can transmit with absolute assurance that the solution will work in certain operating conditions of the real world. As 20th Century educators, we accept the fact that "man collectively" has billions of knowledge elements in his libraries. While we believe with Socrates that every teacher must teach their students ways of finding knowledge and methods of determining truth, we differ radically from the classical epistemologist in our point of departure, in our definitions, and in our approach to the study of knowledge, yet we are talking about the basic problems of teachers from the beginning of time.

We, as 20th Century educators, have a tremendous advantage over Socrates and other classical epistemologists for we can stand with our students in front of our massive seven story library with its millions of bound copies and its interlibrary loan capabilities of obtaining billions of volumes, and realize instantly the enormity of man's collective knowledge. And, we recognize that the Muse did not blow the knowledge to us. As we and our students survey our libraries and watch the traffic of people and books through the libraries, we must accept the fact that "man collectively" has deposited his knowledge in those buildings. We must also accept the fact that 'truth' on many questions resides in those treasure houses of knowledge. Next, we accept that we obtain the answers to most of man's questions by looking in the library. And, we should realize that our major problem in studying knowledge in the 20th Century is determining what knowledge to teach.

As we view the panorama, we must accept the fact that we are part of mankind and that we are interconnected with billions of living humans who will share their knowledge. Also, we are connected with millions of the dead who have recorded their 'truths' about the questions of life, and that we too will make our contributions to what man can know and we pass that knowledge on to future generations.
If you can accept our "point of departure" you think like a neo-epistemologist and are ready to obtain knowledge using a functional approach. We maintain that the educators purpose is to teach students how to solve problems. The most efficient way of problem solving is to use an existing solution wherever possible. How to find the "truth" or a "solution" from among the infinite mass of communications is the educational problem. The knowledge of the disciplines is contained in journals. Recently, Broad (1988) estimated that there are 40,000 scientific journals that are published annually around the world. The knowledge is later organized into textbooks and course offerings.

The concept of "collective-extantism" is grounded on the belief that at any point in time, knowledge is finite and capable of being structured functionally. The neo-epistemologists believes that knowledge is structured in hierarchies, such as

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Total of Man's Knowledge
The Thousands of Disciplines
Functional Operations of the Disciplines
Families of Similar Elements
An Essential Element
```

**Definition of Knowledge**

The common characteristic of all of man's knowledge is man's problem solving techniques. Therefore, the authors define knowledge as the acceptance of a problem solving technique into a person's repertoire of solutions. This definition and the neo-epistemological theory of knowledge requires the modeling of man's problem solving devices according to the evolution of the functional operations associated with the structure of knowledge for a discipline.

Today, knowledge is organized into disciplines. A discipline is a body of knowledge that explains a particular subject. The language arts, mathematics, chemistry, physics, biology, engineering, and music are some of the disciplines among the thousands existing. Each has its own preserve of knowledge, its particular mode of inquiry, its respective technologies, and its specialized instruments.

The knowledge in the discipline should be located and organized functionally. Knowledge is arranged according to the purpose for which it was destined. Disciplines have staked their claim on certain areas of work competencies which the general population expect a particular degree of expertise in the activity being performed.

Knowledge resides in the minds of men wherever they may be. It has it origins in the mind of a single individual who is intent upon problem solving. It stays there until it is transmitted to others. Unless knowledge is transmitted to others, it dies with the individual. Until the advent of the victrola and pressed voice records, knowledge transmitted verbally was particularly fragile for when the voice stopped information ceased to be projected from the mind of the speaker to the mind of the listener. Written knowledge is as permanent as the paper and ink used to inscribe it. Like the Ten Commandments, it may be carved in stone, but until it is accepted in the minds of men, knowledge has no value.
Perhaps, the most difficult of disciplines is the English language. It is certainly the most used and seemingly the least modeled of the disciplines. Consideration of a truncated construction of the model of the structure of the English language may be instructive of the generic process for modeling any discipline.

First, the English language is one part of a large number of communication systems that allow humans to exchange information. As with all disciplines, we recognize that there is now a sizable body of knowledge that is being taught as the English language.

Parents, professional teachers, media personalities, and everyone that the individual communicates with in English is a teacher of the English language. It is our job to step back from our talking and writing and to observe the processes of the English language and to identify and characterize the products. We must analyze what it is that we do when we communicate using the English language and identify the instruments that we use. Next, we must characterize the English language in a model that shows the major functional operations.

If professionally trained individuals intuitively know the structure of knowledge for their discipline it is a wonder that such structures not been constructed before. Surely they would enhance the ordering of knowledge in all fields and would have provided some standardization for students and teachers selecting knowledge for study. The answer, after one starts building such a model, also becomes obvious as the amount of research and development necessary to build a valid model is tremendous. Individual engineers have not made the structure of knowledge for their discipline their first interest as such work would not be recognized by their departments and university colleagues and it would consume vast amounts of their thinking time leaving them without orthodox research accomplishments. The structuring of knowledge for a whole discipline is not the prerogative of any particular engineering group; yet it is of vital interest to every engineer. It is not the prime interest of any one person or any particular department so it belongs to none. At best, this basic taxonomic problem is of secondary or tertiary interest to professionals accustomed to working on the disciplinary imperatives of their field, but ignoring the research on the knowledge of their field.

The ability to first distinguish between knowledge and the other billions of bits of information that daily comes into our consciousness will determine our success as a teacher. Collectively, our success will determine the future.

ENGINEERING STRATEGIES

Time On Task

The Project SUCCEED Study Strategy relies on a Total System Approach to improving engineering education. The Strategy includes the following major steps:

1. The Project staff taught volunteer non-conventional students that all knowledge is functionally organized and that students can chart their own educational destinies if they will study the disciplines' structure and plan their progress in it.
2. The Project students determined at the beginning of the term the Essential Elements of the course material they would master during a particular planning period. Next, they record the time spent on the following study modes according to each Essential Element (Appendix A):
   a. Class Instruction
   b. Independent text study
   c. Small group study
   d. Laboratory instruction
   e. Any other outside aids used.
The integration of time management into the students' study strategies of the essential elements is imperative.

3. The staff aggregated the self-reports and determined the average time spent on mastery of a particular concept or research task and then shared this information with the students. This immediate feedback on their progress in the student study plan allowed the students to take corrective action immediately and permitted the project staff to suggest possible assistance in mastering the essential element.

These techniques determined the time on tasks (Table 1) and allowed the students to chart their progress through the SOK of engineering education.

**Recognizing Student Potential**

Part of the strategy in engineering is recognizing the type of student that is attracted from the high schools. Figure 2 shows the fundamental concepts of an engineering program with an identification of the type of student that would be likely to enter the program. It is a general impression that all students entering engineering programs are a HS-1 type student, one that can jump right in to the mainstream of the curriculum. Unfortunately, many of the non-conventional students do not fall into the HS-1 category for one reason or another. In fact, many students entering engineering programs are the HS-2 or HS-3 type of student. Irregardless of the level of student entering the program, each type of student must be recognized and their program adapted to compensate for any deficiencies. As can be seen in Figure 2, any student not at the HS-1 level will require additional time to complete their program. This in no way should be used as a label for the students and, thus, not accepting them into a specific program. The typing should only be used as a guide to recognize educational deficiencies and identify a plan that will make the student successful in completing the program.

**Engineering Wheel of Knowledge**

Our first step in examining the engineering curriculum was to develop a model that describes the structure of the program. Figure 3 shows the structure of engineering and the material required to train the future professional engineer in what we call the Wheel of Engineering Knowledge. The wheel consist of five primary segments: engineering science, basic sciences, mathematics, communication, and engineering design. In the past, the communication component has been neglected or eliminated from the engineering curricula. The lack of proper communication skills has been recognized as a major stumbling block with engineers, prompting more call for the development of these skills (Rumpf, et
al., 1988; and Amidon-Rogers, 1988). Verification of this need can be recognized by examining the wheel as it rotates around (that is, as the engineer uses the various bits of knowledge to solve a problem) missing any part of the wheel, such as communication skills, will make the travel quite rough.

Another aspect that is revealed by the wheel of engineering knowledge is that if any of the specified segments of the program (or basic fundamentals) have not been mastered by the student, that student will not be able to function on the job at the level required by our advanced technological society (Nandagopal and Sheinberg, 1990). Conversely, inflating one of the segments in relation to the others can also produce some difficulty in the students abilities to adequately perform on the job. A balanced program must be provided and taught to the students as part of their training.

An example of an unbalanced wheel is where an engineering program that does not require their students to take the basic engineering science courses, such as statics and dynamics (Heggen, 1988). Even though some of the engineering disciplines do not involve the level of design that requires a proficiency in the two engineering science fields, the material is essential for the engineer for spatial visualization purposes. The concepts associated with the "Wheel" directs a balanced approach to curriculum restructuring.

Redundancy With A Different Face

Identifying the different laws and principles that are only different in application as opposed to form follows the assumption that there exist some redundancy in the massive amounts of material we are trying to teach students. If concise, coherent programs are to be provided to the students, the quantity of redundant material must be kept to a minimum. This fact is especially true when you consider the annual amounts of new scientific material added to the current supply.

An example of existing redundancy is illustrated by the following linear flow laws currently being taught as three separate laws of science.

\[
\begin{align*}
\text{Fourier's Law for Heat} &\quad Q = k \frac{(T_2 - T_1)}{L_d} \\
\text{Darcy's Law for Water} &\quad Q = K \frac{(H_2 - H_1)}{L_d} \\
\text{Fick's Law for Molecules} &\quad Q = D \frac{(C_2 - C_1)}{L_d}
\end{align*}
\]

Note that each of the equations listed have the same form: an unknown coefficient related to the particular process, a ratio of the cross-sectional area to length of flow, and a driving force mechanism. Unfortunately, when hydraulics, for example, is taught in the typical class, there is no mention of the other laws nor of the fact that the flow principles are similar. If the basic laws and/or
common principles are taught early in the student's career, the task of learning the material would be more efficient. In addition, knowing that the common principle exists, the student is now only trying to memorize one piece of information as opposed to three, or possibly more.

**Specific Programs**

Currently, several research projects are in progress to develop the SOK for math and English. For example, Figure 4 shows the architecture of the knowledge pyramid for math and English in an abbreviated form. At the bottom of the pyramid is the lowest level of knowledge for the specific subject. As you progress upward, the level of knowledge required to master each functional operation increases. Naturally, at the college level, the initial functional operations are already mastered and the higher levels are the focus of attention. Rather than mastering each level of the functional operations before proceeding to the next level, our approach is to assure technical competency of each level.

The pyramid also shows that there will be a specific mode of inquiry that each person will take in order to solve a particular problem. This mode of operation is not well defined, but understanding the possible pathways by the students significantly improves their chances to find the solution. Once the mode of inquiry is known, the next operation is to find the tool or instrument that can be used to assist with the solution. For example, in solving a mathematical problem, a calculator or computer would be used. In English, tools that could be used are the dictionary, thesaurus, typewriter, word processor and other sources in order to maintain proficiency.

**SUMMARY**

A summary statement that encapsulates the problems found in education today is that a thorough knowledge and understanding of the basic fundamentals of science and engineering must be provided to all engineering students. The process of providing changes in the program is continuous and requires an immense effort to maintain a competitive edge. Lack of continually upgrading the program will result in a loss of the economic and technological edge for the United States.

Current programs are the result of a few prestigious institutions set out to create an elegant education, thus not allowing some very capable students into the engineering world. With the predicted lack of engineers in the 21st Century and the problems of attracting and retaining students in the programs, the future looks grim without a major change occurring. One change that must be made is to attract the non-conventional student into engineering.

Another obvious fact is that a 5-year program is not the solution to training future professional engineers. The extended program only allows for an instructor to teach more of their current research interest and not the essential elements of the program. In addition, the problem is not solvable by any single individual but with a team approach.

One approach to restructuring the curriculum for the 21st Century was presented in a three dimensional model that includes several principal partners of society, the stages involved in model adoption, and specific goals within the model. The
concept of the model is to make the approach to the problem complete in order to succeed. Part of the plan includes recognizing the incoming students potential and adopting the system to allow the student to succeed. Another concept of the model is the development of the wheel of engineering knowledge used to describe the structure of the program. The wheel consist of five main segments. If any part of the wheel is missing or incomplete causing an unbalanced program, the student will not be able to perform as expected by industry.

The last and most important concept of the model is the development of the SOK for the different courses within the engineering program. Two abbreviated SOK models, math and Language, were presented. The SOK model includes the functional operations of the material, a mode of inquiry and the tools that assist in solving a potential problem.

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<td>Slope of a line</td>
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<td>Sect. 1.6 Tangent Lines &amp; Slopes of</td>
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<td>vertical line x=a</td>
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<td>point-slope equ.</td>
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<td></td>
<td>y=-y1=m(x-x1)</td>
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<td>y=mxt+b</td>
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<td>horizontal line y=b</td>
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<td>June 6,1990</td>
<td>Derivative of a Function</td>
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<td>Limits</td>
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<td>Def. The limit of F(t) as t approaches c is the number L if: Given any there exists a radius &gt;0 about c such that for all t</td>
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<td>b) Right and Left-Hand Limit</td>
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<td>i) Right and Left-Hand Limits</td>
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<td>Theorem 1 Limit Combination Theorem</td>
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<td>Limit Combination Theorem a) Lim. of Polynomials</td>
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<td>b) Lim. of Quotients of Polynomials (Rational Functions)</td>
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<td>a) Limits of Polynomials</td>
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<td>b) Sandwich Theorem</td>
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<td>b) Limits of Quotients of Polynomials</td>
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<td>The Sandwich Theorem</td>
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<td>71-76</td>
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<td>H.W.</td>
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<td>Definition; The limit of f(x) as x approaches infinity is the</td>
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Figure 1. The basic model for upgrading engineering education (Adapted from Hensley, 1961).
Figure 2. Identifying the fundamental concepts for potential engineering students.
Figure 3. The wheel of engineering knowledge.
Figure 4. Example of the basic structure of knowledge for math and language.