A Systems Approach to Integrating Technical Communications Instruction with the Engineering Curriculum

Cecelia M. Wigal, Ph.D., P.E.
The University of Tennessee at Chattanooga

Abstract

Practicing engineers, industry representatives, and ABET recognize the need for technical communication instruction in the engineering curricula. There are various means for introducing and exposing students to technical communication. In 2000, the faculty at the University of Tennessee at Chattanooga (UTC) initiated an integration of the technical communications instruction (ITC) with the core engineering curriculum. Presently, the ITC program and process is being reviewed and documented using a systems approach. This paper provides an overview of problem solving using the systems approach and a discussion of the ITC program and its present status of definition according to system models.

Introduction

The world we have made as a result of the level of thinking we have done thus far creates problems that we can not solve at the same level (of consciousness) at which we have created them… We shall require a substantially new manner of thinking if humankind is to survive.
–Albert Einstein

Engineers seek solutions for simple to very complex problems. They communicate these solutions to their peers, their management, various internal and external customers, and the general public by corresponding, instructing, analyzing, researching, and presenting. Visuals and document design features as well as state-of-the-art hardware and software enhance an engineer's ability to effectively communicate. Effective use of these tools requires knowledge of (1) what tools are available, (2) how to best integrate these tools, and, most importantly, (3) how the reader and listener best grasp written and orally communicated information.

This paper describes a systems approach to integrating technical communication with the engineering curriculum. To introduce this approach, the basic theory behind systems thinking—including systems methodologies and systems definition—and the relationship systems thinking has with the problem solving process are discussed. In addition, specific tools and models used in systems analysis are introduced. Using some of these tools and models, the paper presents the process being developed for the engineering program at the University of Tennessee at Chattanooga (UTC) that introduces technical communication in the freshmen year and develops competency as the students' programs advance through the senior year.

Systems and Systems Analysis

For every complex problem there is always a simple solution. And it is wrong. –H.L. Mencken

Systems analysis fundamentally differs from traditional forms of analysis. It begins with analysis—separating a study into individual pieces—but emphasizes synthesis—looking at the relationships between parts to form new conclusions. Systems analysis is most often used when confronting complex problems with a variety of variables that cannot readily be quantified and whose structures are not well defined. It uses ad hoc models to represent variables (the environment, components, and alternatives) associated with specific evaluation questions.[1]

Defining a System

Systems can be defined in a variety of ways using terms like interrelationships, goals, parts, and subsystems. For example, DeGreene[2] states that systems are composed of "people, vehicles, computers, power plants, buildings, roads and so forth organized in terms of subtle and superimposed interrelationships." Churchman[3] adds that the interrelationships should be coordinated to accomplish a set of goals. Kast and Rosenzweig[4] and Jenkins[5] add that a system can be broken into subsystems of lower order that also have goals. These secondary goals influence the system goals. DeGreene integrates the above and provides the following definition:

> *A system is a set of elements or subsystems in active interaction as a bounded entity to achieve a common purpose that transcends that of the elements in isolation.*[2]

One has to be careful using this definition, however, because a single phenomenon can be defined several ways based on boundary and content definitions. To ensure consistency in defining systems, Churchman suggests that systems be determined by defining boundaries and content based on five influences:[3]

- The total system objectives and the performance measures of the whole system associated with the phenomenon
- The phenomenon's environment
- The resources of the phenomenon and encompassing system
- The components of the system associated with the phenomenon, their activities, goals, and measures of performance
- The management of the system associated with the phenomenon.

Systems Analysis Methodologies

The systems literature often refers to four specific methodologies that encompass systems and systems analysis—(1) structured systems analysis and design (systems engineering), (2) 'soft' systems analysis, (3) socio-technical design, and (4) cybernetics.[6] All four are used to identify and solve systems problems for various environmental and operational conditions. For example, systems engineering is technique oriented and concerns the whole system, providing a network (or management process) within which to tie many separate and possibly divergent disciplines by taking an iterative, interdisciplinary approach. Specifically, applying systems engineering involves three steps—requirements analysis, iterative top-down design, and bottom-up integration—that are repeated within three life-cycle phases—system definition, system development, and system deployment.[7] The result is an interdisciplinary application of science and engineering that evolves and verifies an integrated and life-cycle-balanced set of system product and process solutions that satisfy customer needs.[8]

'Soft' systems theory is problem- and process- oriented, rather than technique oriented.[9] Soft systems theory takes as its starting point not a problem but a situation in which at least one person has a *feeling* that some elements of a situation or process are problematic and hence worth exploring. The methodology moves from finding out about the situation to taking action within it, and does so not by relying on experience but by doing some careful, formally organized systems thinking about the problem situation.[10]

Socio-technical systems theory is used to define the *behavior* of organizations. Specifically, this theory defines organizations as pursuing a primary task that can best be realized if their social, technological, and economic dimensions are jointly optimized.[11] An application of this approach is DeGreene's examination of how the human, behavioral and social subsystems affect and are affected by the nonhuman (technological) subsystem and how these subsystems collectively affect and are affected by the dynamic social and natural environments in which the larger system is a part.[2]

Cybernetics, the science of control using feedback and communication, also concerns the study of organizations. However, its application is mainly the study of managing organizations.[11] The use of feedback in the analysis of organizations illustrates organizations as adaptive structures that take action in response to environmental changes to maintain a "steady state." The cybernetic approach makes the explanations of goal-seeking behavior possible.[12]

Systems Thinking

Systems thinking is a generalization of systems analysis and encompasses the basic precepts of the four methodologies discussed above. There appears to be no formal accepted definition of systems thinking. However, many advocates of "systems" and "systems theory," and "systems analysis" agree that the aim of systems thinking is to spell out in detail what the whole system is, including its environment, its objectives, and how the objectives are supported by the activities of its parts.[3] Others promote that the whole system is not just the sum of the parts or subsystems; it is a system composed of *interrelated* subsystems[4] with dynamic as well as static interactions. These subsystems should not be studied separately with the idea of putting the parts together into a whole. The starting point should be with the total system and should consider feedback loops and dynamic relationships. This holistic view requires systems thinking to begin with analysis—separating a study into individual pieces—and to emphasize synthesis—looking at the relationships between parts to form new conclusions.

System Models

The real voyage of discovery consists not in seeking new landscapes but in having new eyes.
–Marcel Proust.

Problem solving is the essential motivation for systems thinking—the more we know, the better we can define, analyze, test, and deploy. Being able to decompose a phenomenon into components and understand interrelationships is necessary to effectively and efficiently define/redefine, control, and improve the phenomenon. Specifically, systems thinking directly influences problem definition, bounding, needs and constraint analysis, partitioning, structuring, and alternative analysis.

Models—abstract representations of a phenomenon—are often used to define system boundaries and content and to guide system and process definition, design, and implementation. The initial consideration of a system uses models with a low degree of restriction—for example, input-output, input, output, functional, and process models.[13] As the system definition evolves, models allow for recognition and definition of detailed parts and their relationships. Systems models begin as qualitative models though can become quantitative models as the problem solving process progresses toward design and implementation.

Application of Models

Models are often used with a process-oriented approach to problem solving, such as the structured analysis and design technique (SADT), which supports a traditional system development cycle—define requirements, create solution options, evaluate options, and define a final design.[14] These models support a system architecture that involves operational, functional, technical, and physical subsystem descriptions (see Figure 1.0).

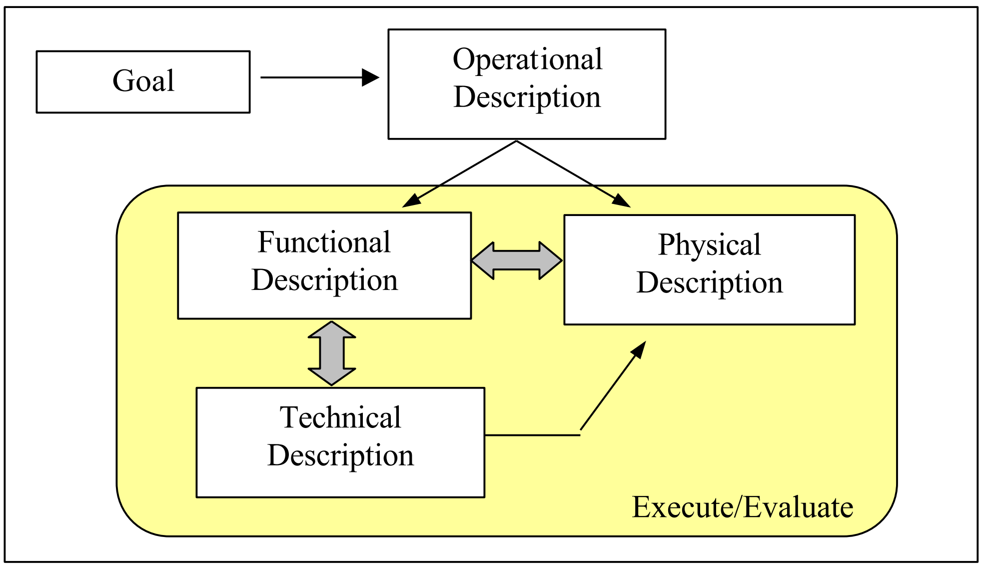

Figure 1.0: Process Approach to Systems Modeling (adapted from Levis[16])

The operational description is a statement that introduces a system by concisely defining how a goal is met. The functional description is a decomposition of the main function of the system into its subfunctions, taking care to define the required inputs and outputs of each subfunction and the behavior of each subfunction. The technical description defines the arrangement, interaction, and interdependence of the elements of the system so that a set of requirements is met. The physical architecture clarifies the physical resources that support and constitute the system, as well as their relationships.[16] These descriptions or architectures evolve through three development phases: analysis (functional and physical descriptions development from the operational definition), synthesis (the dynamic nature of the system and interrelationships defined in the technical description are considered), and evaluation (the performance and effectiveness of the system are considered).[16]

Object-oriented analysis and design (OOAD), a more recent approach to systems development, also utilizes modeling techniques. OOAD, however, is based on objects rather than data or processes. These objects are structures that package component attributes and methods to capture real-world behavior. The boundaries of these objects are clearly defined and the relationships with other objects occur at the boundaries. Objects of similar attributes and/or common behavior or relationships make up a "class" of objects. New classes are developed when objects acquire characteristics from one or more other objects.[14, 16, 17]

As defined by Rumbaugh, the object modeling technique involves viewing a system from the object view, the functional view, and the dynamic view.[16] The object view defines the structure of the system including the various object classes and relationships. The functional view depicts the dependencies between activities of the system. The dynamic view shows the sequence of system events. As is for the structure analysis approach, the three views are brought together to evaluate the entire system. The OOAD model is illustrated in Figure 2.0.

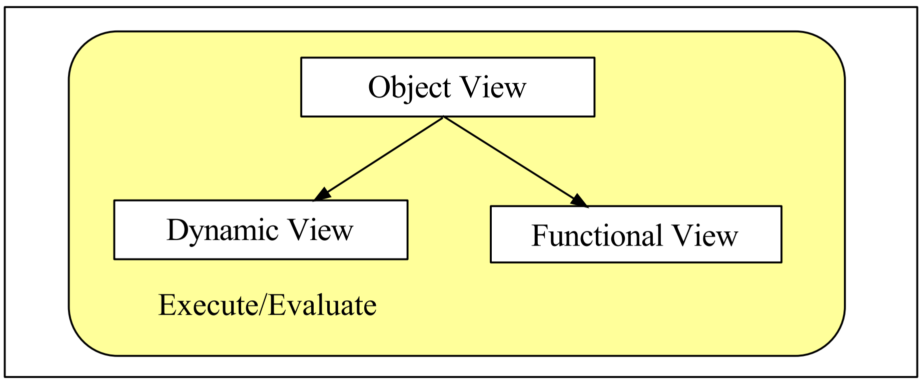

Figure 2.0: Object Oriented Approach to Systems Modeling (adapted from Levis[16])

Need for Integrating Technical Communication with the Engineering Curriculum

Practicing engineers, industry representatives, and ABET recognize the need for technical communication instruction in the engineering curricula. Studies estimate that engineers spend a minimum of fifty percent of their time on some form of written or verbal communication.[18] However, many students see written and oral communication as largely unrelated to their future jobs and/or career goals.[19] Engineering students believe that engineering is understanding and building something and does not include explaining and transferring knowledge, and thus, does not require rhetorical skills.[20]

Many engineering courses require students to compose documents (such as laboratory reports, activity reports, and project reports) and to verbally present project findings or laboratory results. However, Walvoord expresses that engineering faculty, although they know that writing is important are often reluctant to "teach" writing to their students. The faculty worry that their knowledge of technical writing and verbal communication and their ability to constructively respond to student work is limited and their ability to constructively provide feedback to the students is inadequate.[19] In addition, many schools and programs do not recognize the difference between what is being taught in introductory composition courses and industry's needs. Ramey believes that to adequately prepare students for communicating in specific disciplines, students need additional instruction in genre-based writing and verbal communication.[21] Thus, engineering students need instruction in writing and communicating per industry accepted processes and documents.

Some engineering programs address this issue by requiring their students take an additional course in technical, scientific, or research writing. This requirement, however, adds additional hours to the already busy engineering curriculum. Some institutions have created University-wide Writing Centers to provide tutoring and workshop instruction to supplement required composition courses. Ramey states that advising engineers on technical communications requires a variety of techniques and approaches that differ from traditional writing center theory. Specifically, due to the emphasis on design and application, students need to be more directly guided and the instruction has to be product-oriented.[21]

UTC chose to take Ramey's advice and prepare students for the needs of the workplace and further education by providing genre-based instruction. The present status of the resulting process is described below using SAGT (illustrated in Figure 1.0) and the system modeling process approaches described above.

The Systems Model of Integrated Technical Communications (ITC) at UTC

Operationally, UTC's ITC process is the integration of the UTC general education requirements of oral communication and intensive writing with the engineering curriculum. The driver of this integration is the goal to better prepare UTC engineering students for technical communication tasks and expectations of the workplace. The initial process model is shown in Figure 3.0.

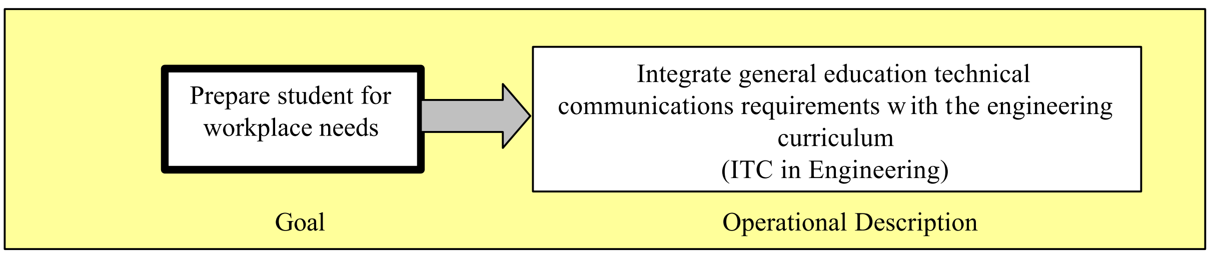

Figure 3.0: Initial ITC Process Model

The operational description provides the foundation for the functional and physical process architectures, which are discussed below.

Functional Architecture

The first step in developing the functional architecture of a system is to develop its functional decomposition (the subfunctions and tasks).[15, 16] The main function of the UTC ITC process is as given in the operational description. The first level subfunctions, provided as verb-noun phrases, include:

- Teach oral communications
- Teach written communications
- Graduate students capable of meeting industry needs
- Provide consistent instruction across disciplines
- Meet UTC general education requirements

The second level subfunctions supporting both the first level oral and written communication subfunctions are identical: instruct topics, practice topics, and assess topics. Further decomposition of the ITC is shown in Figure 4.0.

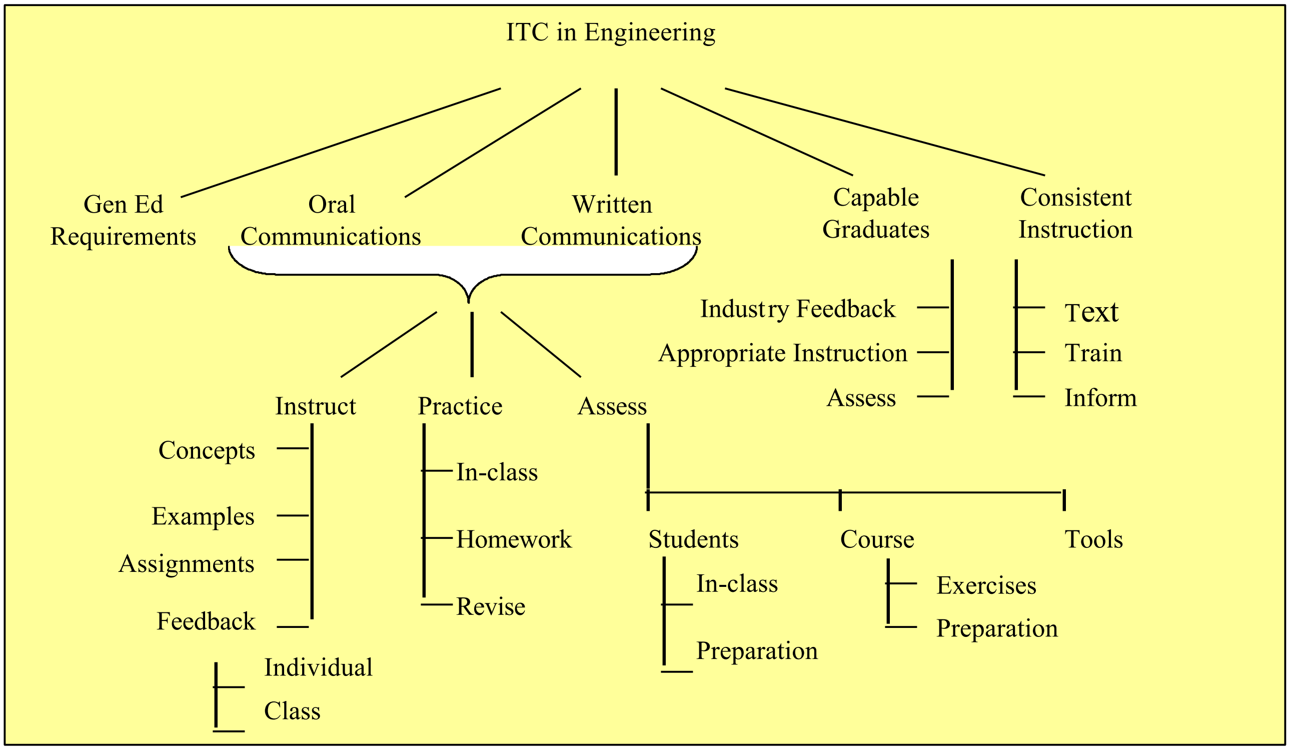

Figure 4.0: ITC Functional Decomposition

Each of the subfunctions can also be illustrated as a box (representing the activity of the function and its subfunctions) and directed arcs (representing transmission of data or objects related to the activity). This exercise ensures that the functional architecture considers all necessary inputs, outputs, controls and supporting mechanisms. For example, Figure 5.0 and Figure 6.0 illustrate two levels of the ITC functional architecture.

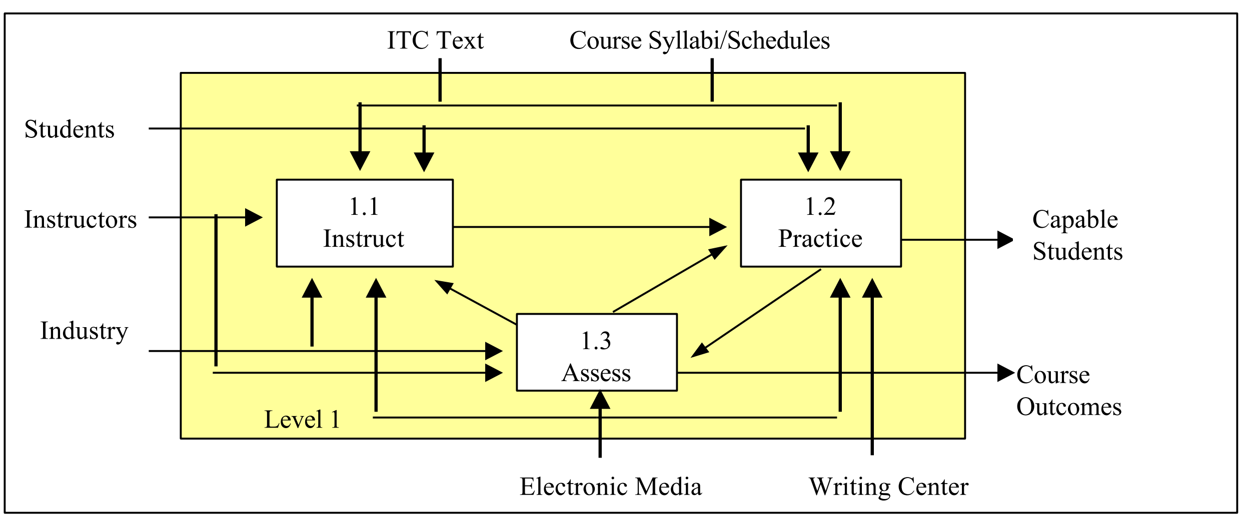

Figure 5.0: Level 1 ITC Functional Block Diagram (Oral or Written Communications)

These diagrams define required controls (inputs from top of diagram), and mechanisms (inputs from bottom of diagram) as well as the inputs and resulting outputs. The remaining subfunctions are illustrated and defined in a similar manner. The result is a functional architecture that defines inputs and outputs as well as most physical and technical interfaces.

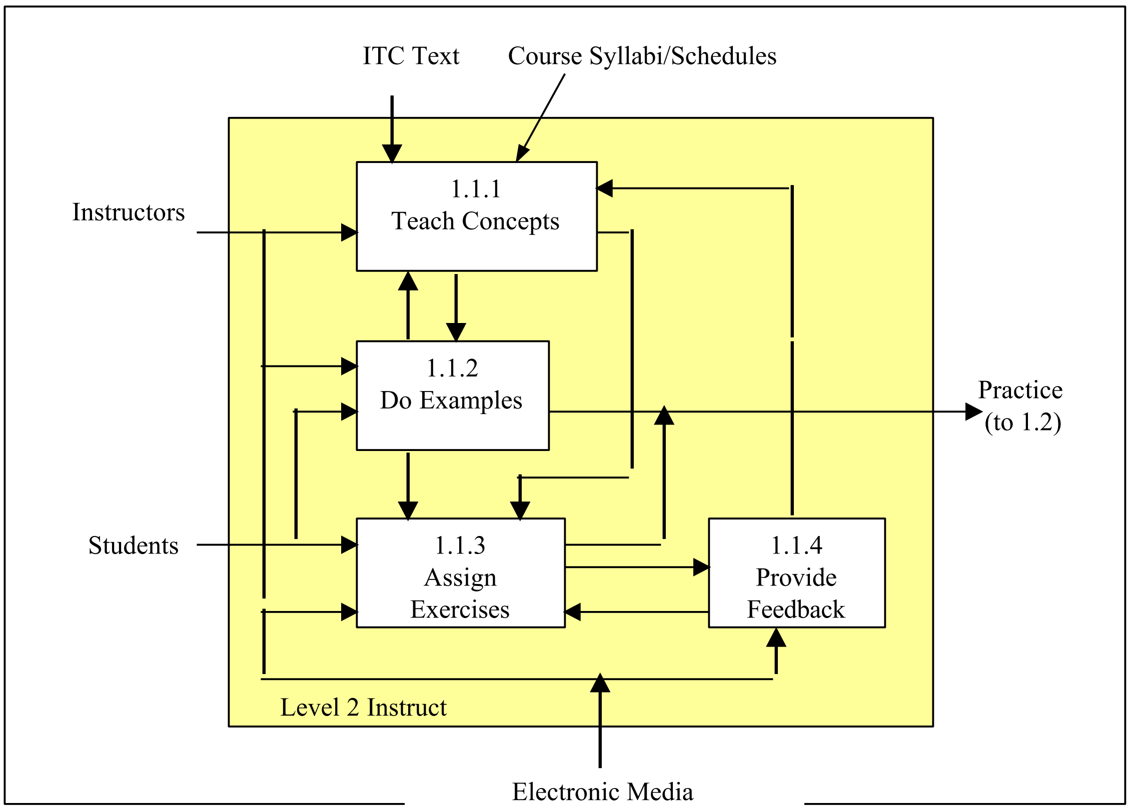

Figure 6.0: Level 2 ITC Functional Block Diagram (Instruct Communications)

Technical Architecture

The technical architecture, which defines the process structure and relationships, initially derives from the functional architecture. Fundamentally, the UTC ITC process structure involves a number of courses across the four-year curriculum. Specifically, the structure of three interdisciplinary design courses—Freshman Design (ENGR 185), Junior Interdisciplinary Design (ENGR 385), and Senior Interdisciplinary Design (ENGR 485)—and four discipline–specific laboratories—Mechanics of Materials Laboratory (ENGR 247), Control Systems Laboratory (ENGR 329), Soil Mechanics (ENCE 361), and Advanced Electronics Laboratory (ENEE 378)—were revised to integrate technical communication instruction. Figure 7.0 illustrates the step structure of the ITC program traversing the four-year curriculum (5 courses per student).

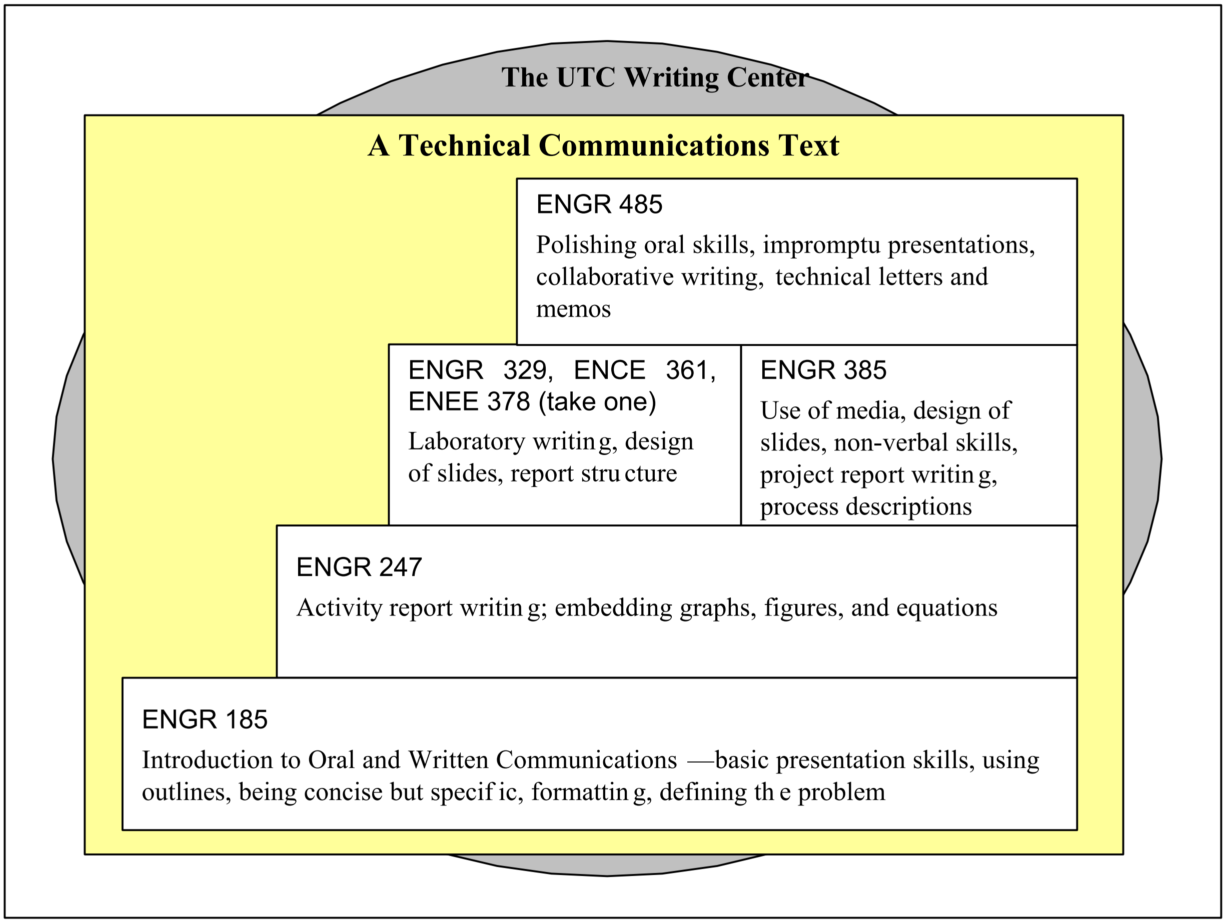

Figure 7.0: The Engineering ITC Program Structure

The technical architecture also defines the ITC prerequisite path and assessment processes so instructors can be assured students are introduced to specific skills, formats, and practices and meet performance criteria as they progress through the ITC program curriculum. Specifically, the prerequisite path provides a means to ensure the students follow the step structure of Figure 7.0. The prerequisite path is illustrated in Figure 8.0.

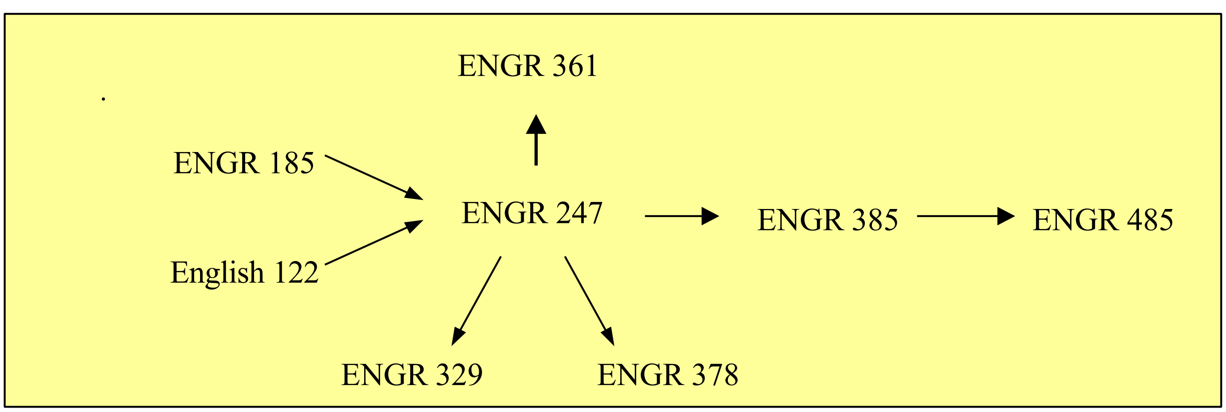

Figure 8.0: The ITC Program Flow (Prerequisites)

The ITC assessment process provides a means to evaluate student oral and written communication competence and course exercise, preparation, and tool use effectiveness. This assessment process is in the design stage. Presently oral communications skills are evaluated at the freshman, junior, and senior levels and written communications skills at all four levels. Assessment tools—check sheets for recording the level of proficiency for each skill addressed at each level—have been developed for each course. The assessment tools, however, have not been integrated, considering the interrelationships of instruction and learning, to provide sufficient indication of progress and effectiveness of the instruction, activities, and tools. Reviewing the functional needs of the program in conjunction with the technical architecture will aid in the finalization of assessment definition and description.

The technical architecture also defines the following:

- Process for meeting the UTC general education requirements
- Process for ensuring consistency of instruction throughout the ITC program courses and from instructor to instructor
- Process for ensuring skills learned support industry's needs.
- Process for training the instructors in technical communications
- Process for effectively utilizing the UTC Writing Center

Definition and documentation of the above processes have been initiated; however, only the process for meeting the UTC general education requirements has been formally defined and documented.

The Physical Architecture

The physical architecture of a system defines the mechanics that support the functional architecture needs. Many of these are defined as inputs to the subfunction block diagrams. For example, with respect to the ITC program, the Writing Center is a support function. If students are having difficulty with grammar and/or sentence structure, they are directed to obtain assistance from the Writing Center. Other supporting functions or mechanics are outlined below:

- Electronic media including projectors, laptops, multi-media cabinets, course websites, etc.
- Program text books
- Program assessment tools
- Program process descriptions
- Communication media for instructors
- Instructor training resources

The formalized definitions and descriptions of relationships of each of these physical components to the functional and technical needs of the program are presently being developed. In addition, as the technical architecture processes become formally defined, additional physical needs may be recognized.

Conclusions

The UTC ITC program was initiated in the fall of 2000. At that time the process for meeting the general education requirements was defined and the ITC program courses and course content with respect to technical communication were identified. However, to ensure the program is assessed with respect to its desired outcomes, procedures, and processes, and that its life is not dependent on an individual project champion, the program is presently being completely defined and documented. The systems approach, specifically the SAGT approach, was selected as the means to document the process because (1) it is a proven technique and (2) the ITC process can be defined sufficiently by its operational, functional, physical, and technical architectures. In addition, it is believed that the modeling techniques utilized by the systems approach provide a fruitful means for identifying supporting mechanisms and needs. It is desired that, upon completion, the fully defined ITC program be a model for documenting other processes in UTC's engineering program.

Bibliography

1. Simon, Herbert (1967) *The New Science of Management Decision*, Prentice Hall, Englewood Cliffs, N.J.
2. DeGreene, Kenyon B. (1973) *Sociotechnical Systems – Factors in Analysis, Design, and Management*, Prentice-Hall, Inc., Englewood Cliffs, N.J.
3. Churchman, C. West (1968) *The Systems Approach*, Dell Publishing Co., Inc.
4. Kast, F. E. and J. El Rosenzweig (1972), "The Modern View: A Systems Approach," *Systems Behaviour*, John Beishon and Geoff Peters (Eds.), Harper & Row, pp. 14 – 28.
5. Jenkins, Gwilym M. (1972), "The Systems Approach," *Systems Behaviour*, John Beishon and Geoff Peters (Eds.), Harper & Row, pp. 56 - 82.
6. Jayaratna, Nimal (1986) "Normative Information Model-Based Systems Analysis and Design (NIMSAD): A Framework for Understanding and Evaluating Methodologies," *Journal of Applied Systems Analysis* Vol. 13.
7. Panitz, Beth (1997) "Training Technology's Maestros," *ASEE PRISM*, Nov. pp. 18-24.
8. Sage, Andrew P. and William B. Rouse (1999) "An Introduction to Systems Engineering and Systems Management," *Handbook of Systems Engineering and Management*, Andrew P. Sage and William B. Rouse (Eds.), John Wiley & Sons, Inc., New York.
9. Checkland, P. B. (1988), "Soft Systems Methodology: An Overview, Department of Systems," *Journal of Applied Systems Analysis* Vol. 15, pp. 27 – 30.
10. Checkland, P.B. (1981) "Rethinking a Systems Approach," *Journal of Applied Systems Analysis* Vol. 8, pp. 3 – 14.
11. Jackson, M. C. (1985) "A Cybernetic Approach to Management," *Managing Transport Systems: A Cybernetic Perspective*, Paul Keys and Michael C. Jackson (Eds.), Gower Publishing Company Limited, pp. 24 – 52.
12. Jackson, M. C. (1988) "Systems Methods for Organizational Analysis and Design," *Systems Research* Vol. 5, pp. 201 – 210.
13. Thompson, Charles W. N. and Gustave J. Rath (1973) "Making Your Health System Work: A Systems Analysis Approach," Annual Meeting of the American Academy of Pediatrics, Chicago, Illinois, October 20 – 24, Revised 1976.
14. Hoffer, Jeffrey A., Joey F. George, Joseph S. Valacich (2002) *Modern Systems Analysis & Design*, third edition, Prentice Hall New Jersey.
15. Buede, Dennis M. (1999) "Functional Analysis" *Handbook of Systems Engineering and Management*, A. P. Sage and W. B. Rouse (Eds.) John Wiley & Sons, Inc., New York, pp. 997 – 1035.

16. Levis, Alexander H. (1999) "System Architectures" *Handbook of Systems Engineering and Management*, Andrew P. Sage and William B. Rouse (Eds.), John Wiley & Sons, Inc., New York, pp. 427 – 453.
17. Oliver, David W., Timothy P. Kelliher, and James G. Keegan, Jr. (1997) *Engineering Complex Systems*, The McGraw-Hill Companies, Inc. USA.
18. Baren, Robert. (January 1993) *"Teaching Writing in Required Undergraduate Engineering Courses: A Materials Course Example."* Journal of Engineering Education, *pp. 59 – 61.*
19. Walvoord, Barbara E. (1997) *"From Conduit to Customer: The Role of WAC Faculty in WAC Assessment."* Assessing Writing across the Curriculum. *Ed. Kathleen Blake Yancey and Brian Huot. Greenwich, CT: Ablex, pp.15-36.*
20. Windsor, D. A.. (1996) Writing Like an Engineer: A Rhetorical Education. *Mahwah, NJ: Lawrence Erlbum.*
21. Ramey, Deanna Elizabeth. (January 2000) *"Assessing Writing Instruction in a Sophomore Engineering Course: Iterations of Integrating Writing from 1995-1999."* Monographs in Engineering Education Excellence. Gateway Engineering Education Coalition/University of South Carolina. Number 1.

CECELIA M. WIGAL received her Ph.D. in 1998 from Northwestern University and is presently an assistant professor of engineering at the University of Tennessee at Chattanooga (UTC). Her primary areas of interest and expertise include complex process and system analysis, quality process analysis with respect to fast-paced growth, and information system analysis with respect to usability and effectivity.