

Introduction to
Engineering Design
The Workbook
King AbulAziz University Edition

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Acknowledgments:

Some of the materials in this workbook were excerpted from a number of sources. In most cases, the original reference or source has been cited. Additions, deletions, changes and other adaptations have been made to the original materials but are not specifically denoted herein. The materials provided by Karl A. Smith, a Civil Engineering professor at the University of Minnesota and expert in Cooperative Learning, are included without citation. Some of the materials and formats were developed by ASU's "Organic" Continuous Quality Improvement Team members Lynn Bellamy, Chemical Engineering, Don Evans, Mechanical & Aerospace Engineering, Eric Guilbeau, Bio Engineering, Darwyn Linder, Psychology, Susan McHenry Malaga, Administrative Services, Barry McNeill, Mechanical & Aerospace Engineering, Jack Pfister, Public Affairs and Greg Raupp, Chemical Engineering. The support of the National Science Foundation under Grant USE 9156176 is hereby acknowledged. Finally, we are indebted to Susan Ledlow in Faculty Development at ASU for introducing us to Cooperative Learning.

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Preface

The material in this workbook has been used in a number of classes at various universities; at Arizona State University it is used primarily in the ECE 100 course, *Introduction to Engineering Design*. ECE 100 is a first year core course; it is a required course for all engineering students. There are many ways an introductory engineering class can be delivered; however, the ECE 100 course developers selected a learning culture, or classroom management style, which incorporates active learning, teams, and 'quality' principles (e.g., continuous improvement and re-engineering). This style is quite different from the styles generally encountered by most students; thus, this workbook was developed to enhance students' understanding of the course material and to assist the faculty who will be delivering the material.

Active learning is **not** something we 'dreamed up' to test on unsuspecting students; rather it is a well researched method of learning that has many long term benefits (you can read about active learning in Sections B and D of this workbook). Most students will find an active learning classroom different; some students will embrace it immediately ("why isn't this used in all my classes"); many students will try the method without really being convinced ("if that is what the teacher wants, I can do it"); a few students will find the approach disturbing ("this is a waste of my time"). The materials in this workbook are intended to: a) help the skeptic see enough of the rationale and tools to at least be willing to try the methods, b) help the willing, but unconvinced, be more comfortable with the methods and to value this learning culture, and c) help the believers engage their classmates in this process.

Creating an active classroom where none has existed before is difficult. It is one thing to agree philosophically with the research data that extol the virtues of active learning; it is an entirely different matter to integrate active learning into a value structure: changing habits learned and reinforced over a lifetime is difficult for faculty as well as for students! This transformation is not complete and may never be complete. This workbook is intended to help both faculty and students focus on the important issues and continually remind all of us that our goal is **student success** in the learning process and in the engineering curriculum.

So kick back, get ready to work, and let's have a great semester, one in which students **and** faculty learn some new, worthwhile, and exciting things!

+LB and BWMcN

SECTION A

How to Use This Workbook

This workbook has been developed primarily for students in the ECE 100 course, *Introduction to Engineering Design*; however, it has been used in other classes and workshops. The files comprising it are also available on the World Wide Web at <http://www.asu.edu/courses/ece100>. In the case of PowerPoint files, the original files will often contain additional information not printed here.

How To Use This Workbook

This workbook has been developed primarily for students in the ECE 100 course, *Introduction to Engineering Design*; however, it has been used in other classes and workshops. It is also available in machine readable form on the World Wide Web (WWW or 'the Web') at <http://www.asu.edu/courses/ece100/>

An Overview

The Table of Contents provides an overview of the workbook. The Workbook has thirteen sections, A to M. Some sections contain the PowerPoint slides that are used in the classroom, while other sections contain a discussion of particular subjects. The PowerPoint slides provide an outline of the major issues or subjects to be discussed in class and are presented in the classroom using a multimedia workstation. Some of the slides in the machine readable version of the Workbook are **not** included in the paper version of the Workbook; these are slides which are intended for a specific class and change from presentation to presentation. For example, slides with instructions for forming specific teams (e.g., number and/or size) are **not** included in the paper copy since they will differ for each specific class; however, they are included in the machine readable version and are presented in the ECE 100 class.

The organization of the workbook sections is **not** unique; the ECE 100 course has been sequenced differently every semester. Students must consult their **course calendar** to determine when the material in a particular section will be used. Students using this workbook for another course can get a rough idea of how the sections might be ordered, and the length of each section, by reviewing the Sample Schedule of Classes at the end of this section.

This workbook can serve as in-class resource as well as a reference source to be used throughout the semester; **bring it to class!** Read the slides to get a preview of each class; reflect on the slides and come to class prepared with a set of questions based on your interpretation of the slides. If the pre-class reading material includes a discussion, additional effort will be required to understand the material; however, reading and developing a set of questions for the class discussion will significantly improve your understanding of the material and your performance in class.

Topics that have been discussed in class can be reviewed in the workbook at any time during the semester. The Competency Matrix in the last section of the workbook may be used as an index to determine the section in the workbook where that topic is introduced and discussed.

Section Content

The purpose of the various sections (and class sessions) is not fully described by the Section or Slide Titles. The workbook can be better utilized if the intent of each of the workbook sections (and class sessions) is well understood; therefore, a brief discussions of each section follows.

- **Section B - ECE 100 Introduction to Engineering: Purpose and Design**

Why does ECE 100 include particular topics? Why is the material delivered using active learning, semester or base teams, and quality principles? How does this course fit in the larger picture of **enabling students to succeed** in the engineering

curriculum? These questions are answered in this section; the educational goals, delivery methods, and the general educational structures used in the class are also discussed.

Students who prefer a broad, holistic understanding of the purpose of a particular class will want to **study** Section B early in the semester. However, students who prefer to learn in a more structured, sequential, style should find this material useful as the class progresses; i.e., they may want to **skim** Section B to get a general sense of the issues, but defer studying the material until later in the semester.

- **Section C - Getting Started (On The Path Of Change)**

The slides in Section C are used to introduce the basic concepts of change; they are also used to set the tone and the structure for an active learning classroom. An in-class presentation of these slides generally lasts about twenty minutes. The agenda on the first slide also includes an example 30 minute introduction to Active Learning (see Section D); however, this is **not** mandatory (i.e., the slides in Section C may be used as the introduction to any of the presentations).

The first three slides provide an example of the general presentation structure used in the class: (1) an agenda listing topics and times, (2) a brief period spent getting ready for class (i.e., transitioning from previous activities to class activities), (3) an outline of the specific goals for the particular class period. Modified versions of these slides are used at the beginning of every class **before** the specific topic is presented.

The specific topics in this section include the subject of **change** as well as some tools and techniques that are used in managing an active classroom. The slides about change are especially important to the students in the course since the classroom experience will require a change in most student's participation, study, and work habits. Students are not expected to fully understand or appreciate these slides at the beginning of the semester; however, the students can return to these slides and review these issues during the semester when they are feeling the pressures of change.

- **Section D - Active Learning**

The slides in Section D are used to introduce active learning. The presentation generally includes short lectures, active participation in a simple active learning exercise (i.e., a simple jigsaw), and class discussion. Most presentations will use a subset of these slides; i.e., only a few of the slides will be discussed in detail. These slides are general reference slides that the students or the faculty may refer to later in the semester.

The specific topics in this section include some tools and techniques that are used in managing an active classroom. One of these tools is the Engineering Journal; **students are encouraged (although not required) to maintain an Engineering Journal during the semester; therefore, this is essential material.** The Engineering Journal is used to encourage reflection, metacognition, and metaprocess; i.e., "If you don't know **how** you did what you did, you can't improve what you do!". Entries from the Engineering Journal can be submitted in the Concepts portion of ECE 100 to improve Quiz grades.

- **Section E - Quality and Process**

Section E introduces the basic concepts of quality. A class presentation based on the material in this section generally includes a mixture of short lectures interspersed with student participation. Quality and what it means is an important topic in ECE 100. Students will want to read this section before class and be prepared to ask clarifying questions. Students will be able to fill in the details during the class discussion and may want to obtain some additional material from the library.

- **Section F - Introduction to Teams**

Section F introduces teams; i.e., what they are and why they are important. This material is generally presented as a short lecture which lasts about 15 minutes; it is used primarily as the introduction to the active learning jigsaw exercise on Team Dynamics (see Section G). A recent, local news paper article summarizing new research on the 'survival of the nicest' (i.e., as opposed to 'survival of the fittest') is also included in this section.

- **Section G - Team Dynamics Jigsaw**

The material in Section G is used in an active learning jigsaw exercise on Team Dynamics. Members of a high performance team must share a certain set of skills, knowledge, and attitudes; this exercise is intended to introduce and practice this important set of skills, knowledge, and attitudes. The ideas and concepts introduced in this session are used continuously throughout the semester; students will need to review these topics later in the semester as they are needed by the semester teams.

The material in this section is almost entirely reading material; it is organized into five topic areas. Students should read **all five** topic areas; however, each student is normally only assigned **one** of these areas to study, understand, and present. The reading may be pre-assigned or may be done in class.

- **Section H - Team Norms and Communication**

Section H presents some concepts and skills needed to develop team social norms (i.e., accepted behaviors). The importance of verbal communication and its impact on team performance is emphasized in this material. Some useful discussion tools are introduced and practiced.

- **Section I - Assessment, Levels of Learning, Degrees of Internalization**

The slides in Section I are used to introduce assessment; i.e., *'how much do you know'* and *'how well do you know it'*. The presentation generally includes an active learning jigsaw exercise followed by class discussion. Competency matrices are introduced as a part of this presentation. The material in this section is rather general; assessment is discussed in more detail in Section J, which also contains the reading material used for the jigsaw included in this session.

- **Section J -**

- A Guide to Presentation, Organization and Assessment of Technical Work**

The material in Section J is related to the presentation, organization, and assessment of technical work products. This material is divided into several parts and should **not** be read in 'one sitting'; however, students should read **all** of the parts and read them in the order presented.

- Section J - *A Guide* ... continued

Part I defines the **faculty expectations** for the presentation of technical work products; students should read this material carefully and use it as a guide for preparing work products. Students whose work products do not meet expectations should reread this material and discuss it with colleagues and with the course faculty.

Part II describes **how to organize** a collection of different, but interrelated, work products. It is almost exclusively a '*how to do it*' section; students should follow the suggested steps when creating the team design notebook or a personal portfolio.

Part III introduces the idea of an assessment **checklist** and explains how to use these checklists to evaluate whether the work is complete (i.e., the work will meet the instructor's expectations). Examples, showing how the checklists are used, are provided.

Part IV addresses **assessment**. Competency matrices (what they are, how they are created, how they are completed) are discussed in some detail. The material will assist students in developing the ability to recognize different levels of learning in work products prepared by other people (and then their own work products). This material may be difficult to understand; students may need to revisit it several.

- Section K - **Tool Box**

The slides in Section K are used to present various quality discussion tools. These discussion tools are very useful in helping teams achieve consensus. Some of these tools have already been introduced in other sections of this workbook. After gaining some experience working with a team, students should browse through these tools to determine if any of them might be useful in accomplishing the next team assignment.

- Section L - **ECE 100 Modeling Assignment # 1**

The first work product that students submit in the Modeling session of ECE 100 is an Excel 7.0 model for a NASA Cone design. This section contains the instructions for preparing this work product. This section also contains information about Excel which will be useful in preparing all of the Modeling Assignments.

- Section M - **Competency Matrix for this Workbook**

The Competency Matrix for this workbook is presented in Section M. This matrix lists the specific topics that the workbook authors feel are most important; it can also be viewed as an index to the workbook. Students are usually assigned to complete this index by inserting page numbers in the matrix to indicate where information on a certain topic is located in **this workbook**.

Sample Presentation Schedule

As indicated earlier, the sections in this workbook are organized somewhat arbitrarily and may be ordered and presented differently. The following sample schedule illustrates how the material in the workbook was incorporated into the set of topics and activities for ECE 100 during the Spring 1999 semester.

Sample Schedule of ECE 100 Topics (based on Spring 1999 semester)

Session	Concepts	Laboratory	Modeling
1	<ul style="list-style-type: none"> • Introduction to ECE 100 (Section B); • Introduction to the Concepts Session (Sections B and C); • Active Learning (Section D) 	<ul style="list-style-type: none"> • Introduction to Laboratory Session (Section B); • Presentation & Assessment of Technical Work (Section J) 	<ul style="list-style-type: none"> • Introduction to Modeling Session (Section B); • Introduction to Excel (Section L)
2	<ul style="list-style-type: none"> • Quality and Process (Section E) 	<ul style="list-style-type: none"> • Introduction to Teams (Section F); • Team Dynamics (Section G) 	<ul style="list-style-type: none"> • Models, Heuristics, Problem Solving
3	<ul style="list-style-type: none"> • Problem Solving: Getting Started 	<ul style="list-style-type: none"> • Peer Assessment; • Freehand Sketching 	<ul style="list-style-type: none"> • Assumptions, Upper & Lower Bounds; • Occam's Razor
4	<ul style="list-style-type: none"> • Problem Definition 	<ul style="list-style-type: none"> • Project 1: Problem Definition 	<ul style="list-style-type: none"> • Predictive Models, • Lumped Parameters, Parameter Estimation; • Salami Tactics
5	<ul style="list-style-type: none"> • Idea Generation 	<ul style="list-style-type: none"> • Project 1: Idea Generation 	<ul style="list-style-type: none"> • Stochastic Models; • Probability
6	<ul style="list-style-type: none"> • Deciding The Course of Action 	<ul style="list-style-type: none"> • Situation Analysis / Decision Analysis 	<ul style="list-style-type: none"> • Stochastic Models; • Simulation
7	<ul style="list-style-type: none"> • Decision Analysis 	<ul style="list-style-type: none"> • Project 1: Implementation / Potential Problem Analysis 	<ul style="list-style-type: none"> • Resource Allocation; • Optimization; • Feasible & Infeasible Solutions
8	<ul style="list-style-type: none"> • Team Norms and Communication (Section H) 	<ul style="list-style-type: none"> • Project 1: Manufacturing / Process Design; • Competency Matrix (Section M) 	<ul style="list-style-type: none"> • Developing & Comparing Strategies; • Trade-Offs; • Validation

Sample Schedule of ECE 100 Topics , continued

Session	Concepts	Laboratory	Modeling
9	<ul style="list-style-type: none"> Implementing Solutions 	<ul style="list-style-type: none"> Project #1: Demonstration 	<ul style="list-style-type: none"> Developing Algorithms
10	<ul style="list-style-type: none"> Levels of Learning and Degrees of Internalization (Section I) 	<ul style="list-style-type: none"> Project 2: Introduction 	<ul style="list-style-type: none"> Comparison of Outcomes; Stability of Solutions
11	<ul style="list-style-type: none"> Evaluation; Ethics 	<ul style="list-style-type: none"> Work on Project 2 	<ul style="list-style-type: none"> Work on Modeling Assignment
12	<ul style="list-style-type: none"> Team Exam (Entire Workbook, Section K) 	<ul style="list-style-type: none"> Work on Project 2 	<ul style="list-style-type: none"> Expert Systems Decision Tables & Trees Production Rules
13	<ul style="list-style-type: none"> Reverse Engineering 	<ul style="list-style-type: none"> Work on Project 2 	<ul style="list-style-type: none"> Individual Excel Evaluations
14	<ul style="list-style-type: none"> Wrap up / Rube Goldberg Exercise 	<ul style="list-style-type: none"> Engineering, the Profession 	<ul style="list-style-type: none"> Modeling Wrap Up
Final Examination: Demonstration of Project #2			

SECTION B

ECE 100 Introduction to Engineering Design:

Course Purpose and Design

Why does ECE 100 include particular topics? Why is the material delivered using active learning, semester or base teams, and quality principles? How does this course fit in the larger picture of **enabling students to succeed** in the engineering curriculum? These questions are answered in this section; the educational goals, delivery methods, and the general educational structures used in the class are also discussed.

Students who prefer a broad, holistic understanding of the purpose of a particular class will want to **study** Section B early in the semester. However, students who prefer to learn in a more structured, sequential, style should find this material useful as the class progresses; i.e., they may want to **skim** Section B to get a general sense of the issues, but defer studying the material until later in the semester.

ECE 100 Introduction to Engineering Design: Course Purpose and Design

A discussion of the educational goals for the course, an explanation of the general educational methods used to deliver the class, and how the course fits in the larger picture of **enabling students to succeed** in the **engineering curriculum** is included in this section of the workbook. The educational goals, delivery methods, and the general educational structures used in the class are also discussed.

Students who prefer a broad, holistic understanding of the purpose of a particular class will want to **study** Section B early in the semester. However, students who prefer to learn in a more structured, sequential, style should find this material useful as the class progresses; i.e., they may want to **skim** Section B to get a general sense of the issues, but defer studying the material until later in the semester.

The presentation is divided into **three** major parts. The selection of the course topics is discussed in the **first** part; a course objectives tree is used to organize these topics. The presentation and delivery of the course topics is the focus in the **second** part. How the design of this course relates to **student success** in the engineering curriculum is addressed in the **third** part.

A. Course Topics

All courses include several different topics, taught to varying degrees of rigor, depth, or completeness. Numerous methods (or models) may be used to organize and present these topics; however, an objectives tree is a particularly useful model. The objectives tree starts with a single, very general course goal, and then proceeds to break that goal into a series of more detailed objectives which are further defined in terms of learning outcomes and competencies (i.e., more detailed objectives). The tree is complete when the class topics have been defined for every learning outcome. This is the method that has been used by the ECE 100 Development Committee¹ to define the course topics. The discussion below provides some insight as to why these topics have been selected.

1. Course Objectives Tree - An Overview

A Bachelor of Science degree in engineering is awarded to students who have developed, mastered, and demonstrated competency of a set of skills, knowledge, and attitudes that will allow them to successfully address the kinds of problems typically assigned to new engineers. The BS curriculum used to transform high school seniors into engineers includes at least forty courses, sequenced with the goal of establishing a broad foundation early in the curriculum. Subsequent courses build on this foundation and provide both breadth of topics, depth within topics and integration among topics.

¹ Bailey, Bellamy, Higgins, Hinks, (J) Kelly, Laananen, McNeill, Moor, Roedel, and Zwiebel

There are numerous topics that could be addressed in an introductory engineering course. Furthermore, there are many different levels at which the material could be learned, ranging from simple recognition of the topic to critical understanding of the material. It is not possible to address all of the potential topics to the highest level of learning in an introductory class; therefore, criteria for selecting topics and levels of learning must be established. The two criteria, or guidelines, used in this selection process were:

1. topics that support the development of the general skills and attitudes needed by all engineers, independent of discipline, are preferred; and
2. topics and levels of learning that enhance the ability of the students to **successfully complete** the **sophomore** courses are preferred.

Using these two criteria, the ECE 100 development committee established the overall course goal, a set of objectives, a set of topics (over 300), and finally a specified level of learning for each topic. It is not possible to show the committee's entire course objectives tree; however, the upper part of the tree² (Figure 1) can be shown, along with a sample³ of the lowest part of the tree (Figure 2)⁴. The lowest part of the tree shown in Figure 2 is associated with the leftmost Learning Outcome (*Learning Culture*) in Figure 1.

These two figures concisely present the thinking of the development committee. As you read **down** the tree, you can see the committee's view on **how** goals and objectives were defined and addressed. As you read **up** the tree you can see **why** the committee selected the topics (competencies) to be included in the course.

For example, reading **down** the left-hand side of Figure 1 shows that the overall Course Goal of Engineering Method includes Self Regulation, which is further defined to include the Learning Culture. Figure 2 shows that the Learning Culture consists of two areas (Essential Elements and Techniques); Essential Elements consists of some nine topics (competencies); and, finally, the level to which these competencies are to be learned is shown by letters in the columns to the right of the competency⁵. Figure 2 shows that the Competency *Learning Pyramid (Cone of Learning)* will be learned at the Knowledge level while *Positive Interdependence* will be learned to a higher level, i.e., Comprehension.

² This is not strictly a tree since several of the boxes have multiple incoming arrows.

³ This is the first page of the course Competency Matrix that defines all the course topics (competencies) and levels to which they are to be learned. The entire matrix is approximately 16 pages.

⁴ The first time reader need only consider the first three columns; i.e., the learning outcomes, competency categories and competencies (or course topics).

⁵ A more complete discussion of these levels of learning (i.e., the columns in the table) can be found in Sections I and J of this workbook. Note that as you move to the right in the table, a greater understanding of the competency is required. You are **not expected** to achieve the levels of learning represented by the gray areas.

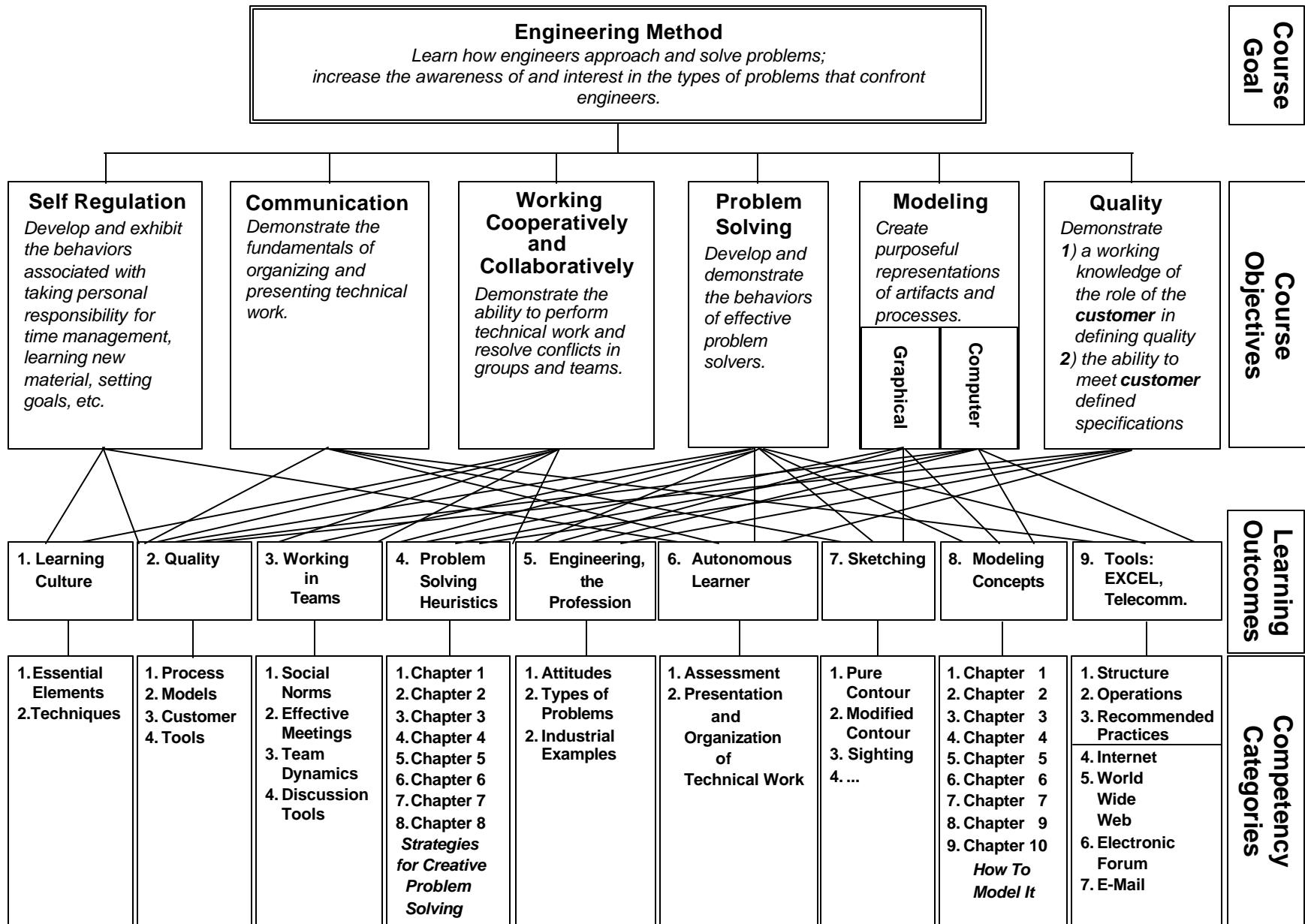


Figure 1 - First Four Levels of the ECE 100 Course Learning Objectives Tree

ECE 100 Introduction to Engineering Design

Name: Smith, Oveyon Guamon

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The letters in each box indicate in which sessions of the class the competency is achieved:
C = Concepts M = Modeling L = Laboratory

Krathwohl's Taxonomy

Bloom's

Affective Objectives

Cognitive Objectives

Learning Outcome	Competency Category	Competencies (grayed boxes are required)	Number ¹	Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1 Learning Culture	1 Essential Elements (Orange Workbook)	Active Learning	1 . 1 - 1	C	C,M,L		C					
		Positive Interdependence	1 . 1 - 2	C	L,M		C					
		Individual Accountability	1 . 1 - 3	C	L,M		C					
		Group (Team) Processing	1 . 1 - 4	C	L,M		C					
		Social Skills Development	1 . 1 - 5	C	L,M		C					
		Face to Face Communication	1 . 1 - 6	C	L,M		C					
		Continuous Improvement	1 . 1 - 7	C	C,M,L		C	C,M,L				
		Learning Pyramid (Cone of Learning)	1 . 1 - 8	C			C					
		Need to Participate	1 . 1 - 9	C	C,M,L		C	C,M,L				
	2	Code of Cooperation	1 . 2 - 1	C	L,M		C	L,M				
		Contact Before Work			L,M		C	L,M				
		Facilitator's Signal			C,M,L		C	C,M,L				
		Issue Bin			L,M		C	L,M				
		Process Check (Plus)			C,M,L		C	C,M,L				

' WHERE the content or topic may be learned'

' WHAT content or topic'

' HOW WELL the content or topic must be learned'

increasing level of difficulty

1 Unique number for each competency

Note : Gray boxes under Affective Objectives and Cognitives Objectives designate levels of learning NOT expected in this course

Figure 2 - Example of Bottom Four Levels of ECE 100 Course Learning Objectives Tree

Conversely, reading **up** the tree (Figure 1) illustrates why particular competencies are included. For example, “Process Checks” are included because they are a “Technique” used in the “Learning Culture”; the “Learning Culture” is included because it supports the development of “Self Regulation” as well as “Working Cooperatively and Collaboratively”; “Self Regulation” and “Working Cooperatively and Collaboratively” are included because they support the learning goal described in the Engineering Method.

Note: Figures 1 and 2 do **not** show **all** of the topics selected. For example, the Figures do not show that Significant Figures and Unit Consistency are topics covered in the Modeling Concepts part of the tree; nor can you determine that Kepner-Tregoe Decision Analysis is covered in the Creative Problem Solving branch of the tree. All of these topics are, however, shown in the complete competency matrix for the course.

2. Course Objectives Tree - Some Clarification

While Figures 1 and 2 show how objectives are defined (reading **down** the tree), the transformation from course goal to course objectives is not unique; furthermore, the Figures provide little insight to explain the transformation. In addition, some of the terms may be inadequately defined or may be interpreted in several ways. Increased understanding can be gained by reviewing the material below.

a) Course Goal - Engineering Method

ECE 100, Introduction to Engineering Design, a Freshman course, is taken by all engineering students. Students should determine early in their programs if engineering is the career they want to pursue; they must be encouraged to view engineering as an exciting field of study; and finally, students should begin, early in their programs, learning the processes engineers use to solve problems. While the students in this class cannot be expected to solve *actual engineering* problems (they are, after all, several years away from attaining the title of engineer), they can be expected to learn the skills, approaches, and attitudes of practicing engineers. Students can practice and improve their problem solving skills by working on non-technical problems (e.g., how to succeed in a subsequent class). Having done so, they will be well prepared to solve technical or engineering problems once they have the technical knowledge germane to their field.

The course development committee was strongly influenced by the work of Billy Koen⁶. According to Koen, the Engineering Method *is a strategy for causing the best change in a poorly understood or uncertain situation with the available resources*. Koen also discusses the strategy used and introduces the use of *heuristics*, which he defines as follows:

- A heuristic is anything that provides a plausible aid or direction in the solution of a problem but is, in the final analysis, unjustified, incapable of objective justification, and fallible.
- A heuristic is used to guide, to discover, and to reveal.

⁶ Koen, Billy Vaughn, *Definition of the Engineering Method*, American Society for Engineering Education, Washington D.C., 1987, c1985.

- The previous two statements are a first approximation, or as the engineer would say, a first cut, at defining a heuristic.

Given Koen's heavy reliance on the use of heuristics, the final definition of the engineering method becomes:

The engineering method is the **use of heuristics** to cause the **best change** in a **POORLY UNDERSTOOD** situation with the **available resources**.

In addition to Koen, the development committee was influenced by the following five issues:

- **Adaptability - Engineering Careers in the '90s⁷**

Adaptability is the **critical** word of the 90's. The Department of Labor tells professionals to expect significant and continuous change. A new college graduate can expect to work 48 years in 5 careers and 12 jobs. Self-reliance, constant training, and flexibility are critical to continued employment. Individuals must be prepared to make lateral moves to build new skills. The only security is in one's skills, experiences, and successes.

- **Emphasis⁸**

The mere formulation of a problem is often far more essential than its solution, which may be a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks a real advance in science.

- **Engineering: In School and Out⁹**

Engineering schools recognize the overlap in industry between engineering and science, and they design their curricula accordingly. Engineering education is strongly theoretical and emphasizes math and science. This emphasis is, in part, based on the natural interests of the people who are attracted to a professorial life and who set the curriculum; however, it is also based on the assumption that engineers can learn the more applied portions of their field on the job, while they are unlikely to learn math and science on the job. Since the activities of the engineering **student** have little relation to the activities of many **practicing engineers**, it is very likely that engineering education discourages some students who would make excellent engineers and encourages others who will not. Performance in engineering schools is measured by the ability to work problem sets and get right answers. In the *predominance of engineering practice*, there are few problem sets and there are never 'right' answers.

⁷ **The Institute**, *The Institute of Electrical and Electronics Engineers*, Volume 16, Number 6, November/December 1992.

⁸ Albert Einstein

⁹ Adams, James L., *Flying Buttresses, Entropy, and O-rings: The world of an Engineer*, Cambridge, MA, Harvard University Press, 1991.

- **Accommodation¹⁰**

It is strange that we expect students to learn, yet seldom teach them anything about learning ... (i.e., the **process** of learning). We expect students to solve problems, yet seldom teach them about problem solving ... (i.e., the **process** of problem solving). Similarly, we sometimes require students to remember a considerable body of material yet seldom teach them the art of memory ... (i.e., the **process** of remembering). It is time we made up for this lack ...

- **What Employers Want**

Employers are the University's 'customers'; the attributes that Engineering Employers seek in their employees should have tremendous impact on the engineering curriculum. In 1988 the U.S. Labor Department reported that employers were seeking employees with the following attributes¹¹:

- Learning to Learn.
- Listening and Oral Communication.
- Competence in Reading, Writing, and Computation.
- Adaptability: Creative Thinking and Problem Solving.
- Personal Management: Self-Esteem, Goal Setting/Motivation and Personal/Career Development.
- Group Effectiveness: Interpersonal Skills, Negotiation, and Teamwork.
- Organizational Effectiveness and Leadership.

Boeing Corporation currently publishes the following list of desirable employee attributes:

1. A good understanding of engineering science fundamentals ...
2. A good understanding design and manufacturing processes (i.e., understands engineering).
3. Possesses a multi-disciplinary, *systems* perspective.
4. A basic understanding the *context* in which engineering is practiced: economics, including business practices; history; the environment; customer and societal needs.
5. Good communicator: written, verbal, graphic, and listening.
6. High ethical standards.
7. An ability to think both critically and creatively - independently and cooperatively.
8. Flexibility - an ability and the self-confidence to adapt to rapid/ major change.
9. Curiosity and a desire to learn for life.
10. A profound understanding of the importance of teamwork.

¹⁰ Norman, Don A., Cognitive Engineering and Education, in D.T. Tuma and F.R. Reif (editors), *Problem Solving and Education: Issues in Teaching and Research*, Hillsdale, Lawrence Erlbaum, 1980.

¹¹ *Workplace Basics: The Skills Employers Want*, American Society for Training and Development and U.S. Department of Labor, Employment and Training Administration, 1988.

Finally, the development committee relied heavily on a new text by Wankat and Oreovicz¹² for guidance on Piaget's and Perry's theories of learning and college student development, constructivist theory, assessment, course objectives, and various taxonomies, as well as the use of technology in teaching.

b) Course Objectives (the Upper Level)

The Objectives shown in Figure 1 are rather broad. Since students in all engineering disciplines take the course, it is appropriate to focus only on the broad, cross disciplinary skills and attitudes, rather than on narrower, discipline-specific topics. Further, this approach allows the course to better support a wide range of subsequent sophomore classes.

Figure 1 shows the Course Goal further defined with six Objectives. These Objectives reflect six important areas that need to be developed if a student is to become proficient at the Engineering Method. The first four and the last one of these reflect objectives that are consistently identified by national panels and workshops charged with describing the ideal Bachelor of Science engineering graduate. The fifth Objective (Modeling), while not generally cited explicitly by these panels and workshops, is always implicit in their recommendations and is an important tool for any engineer in the 21st century.

(1) Self Regulation

Self regulation is a term used extensively in the current literature. The April 1995 issue of *The Teaching Professor* discusses this topic, using an article written by Barry J. Zimmerman¹³ as its source of material. Zimmerman writes:

Since the founding of the republic, American educational leaders have stressed the importance of individuals assuming personal responsibility and control for their own acquisition of knowledge and skill.

He goes on to describe the self regulated student as follows:

They approach educational tasks with confidence, diligence, and resourcefulness. ... Self-regulated learners are aware when they know a fact or possess a skill and when they do not. ... Self-regulated students pro-actively seek out information when needed and take steps to master it. When they encounter obstacles such as poor study conditions, confusing teachers, or abstruse text books, they find a way to succeed.

Some characteristics of self regulated learning are:

- Self-regulated learners plan, set goals, organize, self-monitor, and self-evaluate at various points during the process of acquisition.

¹² Wankat, Philip C. and Oreovicz, Frank S., *Teaching Engineering*, McGraw-Hill, 1993.

¹³ Zimmerman, Barry J., "Self-Regulated Learning and Academic Achievement: An Overview", *Educational Psychologist*, 25, 1990, (1), pp. 3-17.

- Self-regulated learners monitor their strategies and modify as appropriate (i.e., they utilize self-oriented feedback).
- Self-regulated learning involves more than a capability to execute a learning response by oneself (i.e., self-control) and more than a capability to adjust learning responses to new or changing conditions from negative feedback. It involves proactive efforts to seek out and profit from learning activities. At this level, learners are not only self-directed in a metacognitive sense but are self-motivated as well.

(2) Communication

Engineers generate massive amounts of technical work products when they solve problems. Long term success at problem solving requires that these work products be organized and presented in a manner that facilitates the transfer of ideas from one person to another. In addition to written communication, the ability to verbally transfer ideas is essential in engineering. Dick Balzhiser¹⁴ from the Electric Power Research Institute notes:

George (Heilmeier of Bellcore) already mentioned communication skills, but I think they can't be overemphasized. Will your graduating engineers be comfortable going out and talking with the people on the factory floor? Will they be comfortable taking with local environmentalists, union officials, and everyday citizens?

Tommy Hodge¹⁵ from Milliken and Company states:

At Milliken, our engineers have to write about and stand up and explain improvements that they've made.

(3) Working Cooperatively and Collaboratively

Engineers work in teams to solve problems. When problems are vague, teams help clarify the problems and generate potential solutions. When problems are clearly defined, the problems are generally too involved for a single person to solve; thus, teams of experts are used. Tommy Hodge¹⁶ states:

The individual out working on a job is a thing of the past. People have to be able to work together and function in teams. Our engineers think students need more experience with this. Of particular importance are conflict resolution skills -- being able to convince others that your idea is the best, or being able to get a group consensus.

(4) Problem Solving

While each engineering problem may have a unique solution, the underlying approach used to develop the solution is not unique. Effective problem solvers have a generic

¹⁴ "Educating Tomorrow's Engineers", ASEE *Prism*, May/June 1995, pp. 11-15.

¹⁵ Ibid., p. 11 - 15

¹⁶ Ibid., p. 11 - 15

approach and attitude that increases their probability of success. Problem solving also involves critical thinking.¹⁷

(5) Modeling

Problem solving includes making predictions about what will happen (e.g., will the dam hold, will the plane be able to take off, will the microprocessor actually operate at 200 Mhz, etc.). Such questions are often answered through the construction and study of models. Engineers create and use models continuously as they move through the problem solving process. Models can be conceptual, mathematical, physical, or visual; they can be purely empirical, or based on detailed theory. Mathematical modeling receives particular emphasis, and sketching is practiced as it is important for representing visual models.

(6) Quality

Quality is a term that appears everywhere. It is a term that has a wide range of meanings and definitions. Section E of this Workbook introduces some of these quality ideas and issues. Because there are only a few quality topics covered explicitly in the course, quality was not initially listed as one of the Learning Objectives. However, the course faculty have come to realize that while there may only be a few specific topics covered, much of what they do is directly related to helping students learn how to work in an environment where quality, not “correctness of an answer”, determines the success or failure of the effort. Therefore, quality has been added to the Learning Objectives.

c) Learning Outcomes (and Lower Levels)

There are multiple sets of Learning Outcomes that might be used to meet or accomplish the Course Objectives (and thus the Course Goal). The ECE 100 development committee selected the set of nine Learning Outcomes shown in Figure 1.

Figure 1 shows that all Learning Outcomes support at least two Objectives and several support three or more Objectives. For example, the fourth Learning Outcome, Creative Problem Solving is included because it helps develop Working Cooperatively and Collaboratively as well as the attitudes needed to Solve Problems.

The Learning Outcomes are still general in nature; the specific topics addressed are included in the Competency categories of the tree. The following material briefly discusses each Learning Outcome and the topics included. The criteria used to identify Course Objectives were also used to select specific competencies; i.e., are the topics germane to all engineering disciplines and to sophomore level classes.¹⁸

¹⁷ Fogler, H. Scott and LeBlanc, Steven E., *Strategies for Creative Problem Solving*, Prentice Hall, 1995.

¹⁸ Some topics which are often found in core courses, e.g., Engineering Economics, CAD/CAM, Probability and Statistics, technical report writing, etc., were not included; they were not compatible with the other material included in the course.

1. Learning Culture

The learning culture, i.e., the way the course is delivered, is based on an active learning, and a modified constructivist¹⁹, model. Monitoring and continuous improvement in the learning process are important aspects of this Learning Outcome. The students can be expected to increase their opportunities for success in subsequent courses as a result of successful participation in this new learning environment.

2. Quality

Quality is an essential aspect of all student activities. For example, it affects the type of homework they submit; it defines the grade they receive in a class. The important role of the customer in defining quality and the concept that quality is related to meeting or exceeding customer expectations is introduced and used. Process and the continuous improvement of processes are also presented. If students can begin to understand how faculty assess work and reward quality, they should be prepared to participate more successfully in their later classes.

3. Teaming

Teaming is further defined by four Competency Categories (Social Norms, Effective Meetings, Team Dynamics, and Discussion Tools). The purpose of the topics included is to allow groups of students to learn how to work together as a team. As the Competency Matrix illustrates, it is expected that the students will be able to create social norms for a team, hold effective meetings, and use a variety of discussion tools to aid in the development of team consensus.

4. Creative Problem Solving

Creative problem solving addresses the development of the skills and attitudes that successful engineers use in solving problems. In ECE 100 this material is delivered using *Strategies for Creative Problem Solving* by Fogler and LeBlanc. The strategy developed can be used to address any type of problem; thus, the course uses problems appropriate for the technical skills and knowledge level of Freshmen. Since the skills and attitudes are general in nature they are useful in any future class, including those immediately following this course.

5. Engineering the Profession

This learning outcome offers students the opportunity to gain some understanding of what engineers actually do and, therefore, the opportunity to determine whether engineering is the career they wish to pursue. The class is designed to have the students experience the attitudes expected of engineers and to provide some insight into the types of problems that various engineering disciplines address. This has limited direct impact on, or relation to, following courses; however, it is important in motivating students to complete a lengthy and difficult program.

¹⁹ Constructivist learning is a method in which the students are assigned a task with minimal or no prior preparation. The students work on the task until they can not progress any further **and** they recognize their need for information or guidance; at this time an appropriate learning experience can be delivered. This may be viewed as a 'just in time' approach based on the **students'** perception of need.

6. Autonomous Learner (Life Long Learner)

This Learning Outcome provides students with the ability to assess the level to which various topics have been learned. The material focuses on learning how to recognize the attributes of written work that are indicative of the various levels of learning and includes material related to presentation of technical work. Presentation and assessment of technical work are complementary. The ability to present quality work will be useful in all following classes.

7. Sketching

The ability to present ideas using sketches is considered an important learning outcome. Virtually all-engineering work requires sketches as part of the presentation of technical work; thus, these skills will be used in several following classes.

8. Modeling Concepts

Modeling concepts address the development of the skills and attitudes successful engineers use in developing models. The actual models developed are not as important as the process used to create the models. In ECE 100 this material is delivered using *How to Model It* by Starfield, Smith and Bleloch. All engineering classes use models; thus, the basic skills and attitudes developed are immediately useful in all following classes.

9. Tools: Excel / EMail / Internet / World Wide Web

It is important that students become comfortable using computers and the computing tools available on personal computers. It is desirable to move the students toward valuing the computer and what it can do. It is also important for the students to realize that there are generally multiple tools from which to choose. The course uses Excel, a spreadsheet, as the tool for constructing the models created in the class. Students are expected to become comfortable and proficient with Excel as they work on creating models. The competencies involve specific spreadsheet operations as well as spreadsheet design and construction. Furthermore, the students are expected to use Email and the Internet to communicate with the course instructors and to access the course materials (weekly calendar, assignments, etc.) located on the World Wide Web home page for ECE 100. These skills are potentially useful in all following engineering classes.

B. Management (Delivery) Of The Course

With the exception of the first Outcome, *Learning Culture*, the course objective tree (see Figures 1 and 2 as well as the course Competency Matrix) **defines** the course topics; however, it gives little insight into how these topics are presented, what type of work products will be expected, who designs the problems to be worked, how the work products are assessed, etc. Success in ECE 100 can generally be enhanced when these course management issues are understood. The following material (1) addresses active learning (See Section D for additional information on Active Learning); (2) addresses how the three sessions of the course are designed and how the topics are distributed; (3) provides some general comments about the assessment philosophy that has been adopted by the course faculty; and, (4) concludes with a brief discussion addressing the need for everyone to participate in order to assure student success.

1. Active Learning

Considerable thought has gone into the management of this course. The ECE 100 development committee has endeavored to use management techniques that are known to be pedagogically sound. A review of current education journals and/or educational research finds article after article extolling the benefits of some aspect of active student involvement in the learning process. The evidence is overwhelming; therefore, the development committee felt that active learning should play a major and significant role in the delivery of the course topics.

a) Information Restructuring

The decision to use active learning in the classroom is based on extensive research about how people learn. This research shows that long term learning occurs when the “learner” integrates the new information with the information they already have to create a new body of knowledge. This process is known as restructuring; the active learning classroom encourages restructuring. C. T. Fosnot²⁰ states:

These problems are endemic to all institutions of education, regardless of level. [Students] sit for 12 years in classrooms where the implicit goal is to listen to the teacher and memorize the information in order to regurgitate it on a test. Little or no attention is paid to the learning process, even though much research exists documenting that real understanding is a case of active restructuring on the part of the learner. Restructuring occurs through engagement in problem posing as well as problem solving, inference making and investigation, resolving of contradictions, and reflecting. These processes all mandate far more active learners, as well as a different model of education than the one subscribed to at present by most institutions. Rather than being powerless and dependent on the institution, learners need to be empowered to think and to learn for themselves. Thus, learning needs to be conceived of as something a learner does, not something that is done to a learner.

This idea that learning is more than information transfer is not new; paraphrasing²¹ Benjamin Franklin:

Students are not receptacles; information transfer alone is not education. Education is what remains after the information and training have been forgotten.

²⁰ Fosnot, C.T., *Inquiring Teachers, Inquiring Learners*, NY, Teacher College Press, 1989.

²¹ Robert M. Hutchins, *The Learning Society*.

b) What is Involved

The purpose of the active learning model is to encourage students to be mentally, emotionally, and physically engaged in the process of learning. The number of methods and techniques that can be included in this definition seems infinite; consequently, it is impossible to engage the students in all of the possible active learning experiences. The course does use student teams, continuous improvement of the learning process²² and constructivist²³ learning exercises in class. This means students can expect:

- to participate in small group discussions and make presentations to the class,
- to be assigned problems they don't believe (at first) they can solve,
- that some of the classroom instructions may be unclear,
- to find that other students may have different interpretations of what is expected,
- to be a team leader, team recorder, and team member at different times,
- to help other students understand the course material at the request of the course faculty,
- to be asked to suggest ways for improving the class,
- that at some point a team member may ask her/him to modify the way she/he behaves,
- to be an active participant during most class periods.

It has been the course faculty's experience that students who participate, even when they occasionally falter, have a much easier and more enjoyable experience than students who resist participating. In fact, the course faculty feel so strongly about this issue that they have included participation as part of the course grade.

The students will **not** be engaged in all of these activities all of the time; however, the learning experiences in this course are designed to encourage participation in each of these activities and it is hoped that many of the students will be doing several of these unconsciously (i.e., without explicit instructions from the faculty) by the end of the course.

2. The Three Course Sessions

The course development committee decided to deliver the course topics in three different learning environments and, therefore, defined three different sessions for the course. The three sessions are Concepts, Laboratory, and Modeling.

²² The material in this 'Orange Workbook' is supplied to help you understand and function in an active, team based classroom.

²³ A simple constructivist class exercise is organized as follows: teams are assigned a problem but are not given any suggestions on how the problem might be solved. The teams work until they are unable to proceed. At that time either some guidance is provided by the instructor, or teams share (with other teams) their views on how to proceed. The teams then continue working on the problem and the cycle is repeated.

Assigning topics to one or more of the three sessions evolved during the initial offerings of the class. The Course Competency Matrix (Figure 2) has been used to specify the topics assigned to each session. The session is indicated by the letter shown in the various columns of the matrix. For example, Figure 2 shows that Competency 1.2-1, *Code of Cooperation*, is covered at the Knowledge level in Concepts (**C**) and at the Comprehension level in Laboratory (**L**) and Modeling (**M**).

a) Concepts Session

The important concepts are **first** introduced, examined, and tested in the Concepts Session; these are large classes. A mixture of short lectures, group work, quizzes, and videos is employed to deliver and assess the material. Generally, it is assumed that the students have read the material related to the topic **prior** to the class meeting; therefore, class time is used to assess what has been learned, clarify the reading, and, in small groups, test the ideas that have been presented in class. Thus, group work is required during class and individual work is required outside of the class.

The Engineering (or Academic) Journal is also used in the Concepts Session to initiate the reflection process which includes both Self Regulation²⁴ and Information Restructuring²⁵. This journal is designed to be used for recording, or documenting, **and continuously improving** the student's learning process through student reflection upon the assigned textbook reading. It also provides an additional opportunity for student's to reflect on their learning experience. Reflective learning²⁶ has been identified as an important facet of becoming an autonomous or life long learner.

b) Laboratory Session

All of the work in the Laboratory Session is team based. In Laboratory, the teams are assigned a broad problem context and are then expected to work a number of smaller problems that are consistent with the specified context. The general problem provides a series of opportunities for the teams to practice and master the specific concepts introduced in the Concepts Session. The Laboratory Session is somewhat less structured than the Concepts Session.

There are two general problems assigned; one that culminates in the development of a process (an assembly process), and one that culminates in the development of an artifact (a mouse trap powered device). As in the Modeling Session, the actual final work **product** (process or artifact) is **not as important** as the **process** the teams used to develop the work product. The students will be continually encouraged to reflect on and document their decision process; i.e., the reasons they decided to do what they did.

²⁴ Zimmerman, Barry J., "Self-Regulated Learning and Academic Achievement: An Overview", *Educational Psychologist*, 25, 1990, (1), pp. 3-17.

²⁵ Fosnot, C.T., *Inquiring Teachers, Inquiring Learners*, NY, Teacher College Press, 1989.

²⁶ Prescott, Susan, *Cooperative Learning and College Teaching*, New Forums Press, Stillwater, Oklahoma 74075, Fall 1996, pp. 10 -11.

c) Modeling Session

The Modeling Session is the smallest class and is delivered in computer classrooms in which the ratio of students to computers is 2 to 1. The students are expected to work in small teams to build models and present intermediate work products to the class. A constructivist approach is used (the approach suggested and supported by the text book, *How to Model It*) in which students are given a new problem and asked to start developing models that could be useful in solving the problem. The Modeling Session concentrates on encouraging the students to think about **how** they created their models, and **why** they created them; the final work **product** (model) is **not as important** as the **process** the students used to develop the work product or model.

3. Assessment

How work products are assessed, i.e., how student learning is assessed, is one of the more important learning tasks of the course. The course development committee concluded that (1) students need to become familiar with the way work products are assessed, and (2) this assessment process should focus on the quality of the work product. Learning how to assess technical work products, based on their quality, gives students an opportunity to practice (and learn) many of the competencies that are included under the Learning Outcomes of *Quality*, *Creative Problem Solving*, and *Autonomous Learner*. This assessment process requires the students to identify the customer(s) for the work product(s) and to understand the role played by customer expectations in determining if, and when, work products can be assessed as quality work. The assessment process is difficult; however, the long term benefits²⁷ gained from learning and using this process are well worth the short term difficulties.

a) Assumptions

Several assumptions, emanating from the quality principles developed by Deming, Kano, and others have influenced the design of the assessment process. It is assumed that:

- A. quality **cannot** be **defined**, however, it can be **recognized** by the customer when it is present²⁸,
- B. quality is determined by the customer **not** the supplier,
- C. it is only possible to do your job well when you understand what is expected (know **what** to do, **how** to do it, and **why** it needs to be done) , and
- D. everyone wants to, and can, do quality work.

²⁷ The process gives students an opportunity to begin developing the important customer/supplier attitudes that are needed in today's successful engineering enterprises.

²⁸ Pirsig, Robert M. , Zen & The Art of Motorcycle Maintenance : An Inquiry Into Values, William Morrow, N.Y., 1974.

b) The General Process

Work products are assessed using the following terms: **meets** expectations²⁹, **exceeds** expectations, or **needs improvement**. This division into three distinct categories is used to assess: 1) submitted work products, 2) session activities (e.g., quizzes), and 3) session participation. The general process used in assessing an activity or work product is shown in Figure 3. The figure shows the important tasks for the people associated with the course. The student is assigned the task of **doing** the work, **self assessing** the work, and **correcting** any work that needs improvement. The Grader/Faculty are assigned the task of assessing the work to determine if it meets expectations on the first submittal (**or** on subsequent resubmittal, if required). The Faculty are responsible for establishing the expectations and determining when a work product exceeds expectations.

c) Discussion of the Process

The process shown in Figure 3 includes a number of implicit issues that need to be emphasized.

1. The Role of Expectations

Figure 3 shows that to be successful (i.e., to do work that meets or exceeds expectations), the student must know, in advance, what is expected. The figure shows that these expectations are developed by the Faculty **before** the work is assigned. In this process, the **Student** is viewed as the **supplier** of a product (e.g., a homework assignment or work product) and the **Faculty** are viewed as the **customers** for the products. The course Faculty have developed a comprehensive set of expectations for each of the sessions (see examples in Section J, Appendix C).

2. Needs Improvement and Exceeds Expectations

A crucial aspect of the process, **one often overlooked**, is that **ALL parts** of a work product must **meet** expectations **before** the work product can be reviewed to determine if it **exceeds** expectations; i.e., there is **no** “partial credit” for partially meeting expectations. If **ANY part** of a work product being assessed does **NOT** meet expectations, then the **entire** work product is assessed as **Needs Improvement**³⁰. This fact can be very disheartening; therefore, it is **critical** that the students realize they must attend to **first things first** (meet expectations) **before** spending any time or effort to exceed expectations.

²⁹ We are using the term *expectations* to refer to things that **MUST** occur (be present); i.e., we are not referring to things which we **HOPE** will occur (be present).

³⁰ It does not matter how wonderful a company's bid for a potential contract is, if the bid fails to present the material in the form requested (e.g., fails to have page numbers on all pages of the bid), the bid may be rejected and the company will lose a chance to compete for the contract.

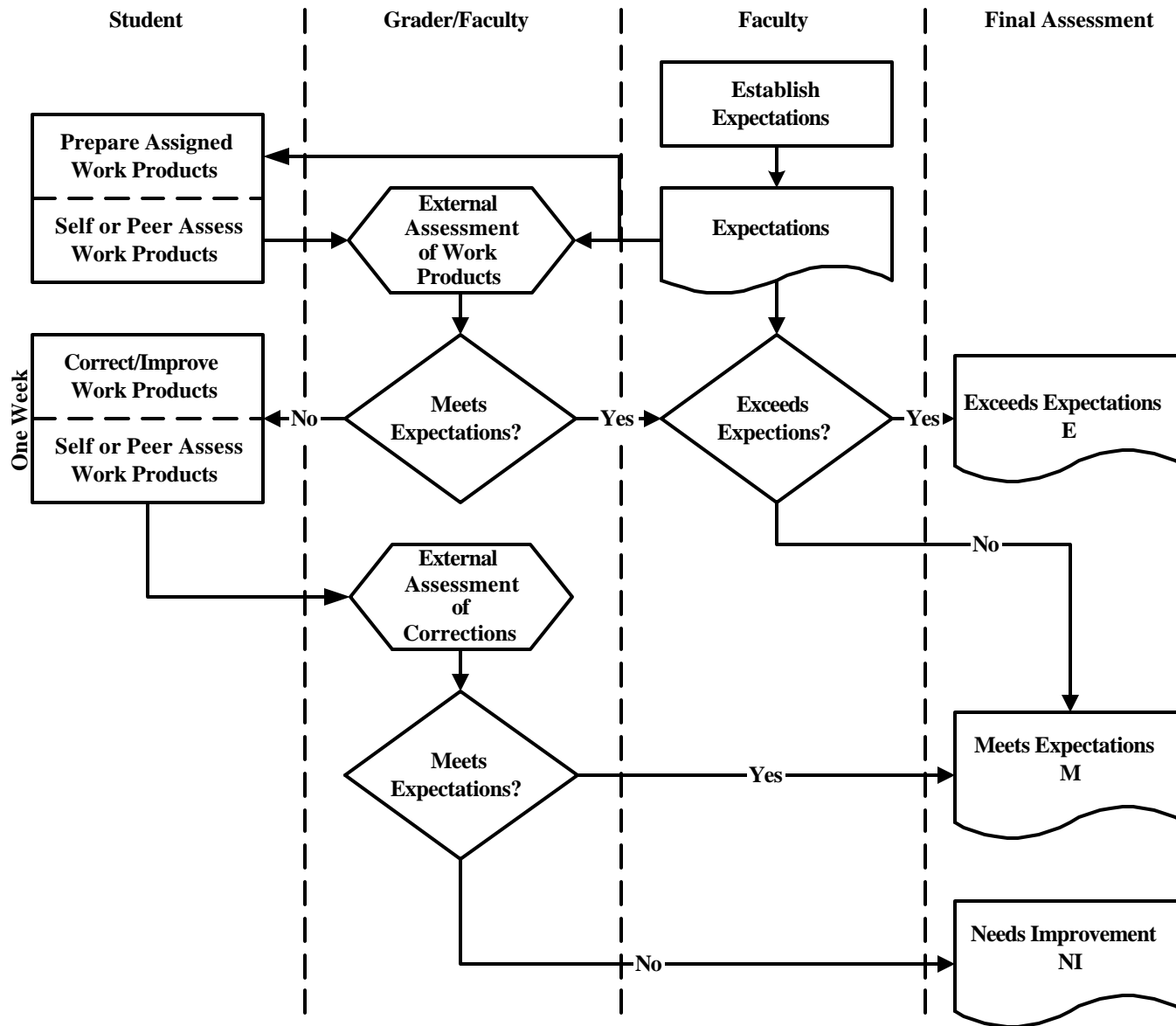


Figure 3 - Activity Assessment Deployment Flowchart

3. Exceeding Expectations - What Does It Take

As indicated in *a) Assumptions* above, it is **not** possible to define, in advance, a product that exceeds expectations; however, it **is** possible to recognize that expectations have been exceeded when the customer actually sees the product. Determining what 'features' may excite the customer is often a trial and error process; students often fall short a few times before determining what their customers (i.e., the session instructors) believe exceeds expectations. Students generally want some suggestions about what might exceed expectations; these are difficult to provide. However, the following items describe some **approaches** that might lead to a work product that exceeds expectations:

- demonstrating a level of learning beyond that asked for in the original assignment;
- examination of one or more relevant parameters beyond what was originally assigned;
- insightful reflection on the role of the assignment in achieving the learning objectives of the course, or on the role of the assignment in the student's own learning;
- recognizing and answering relevant questions beyond what was originally asked;
- obtaining and discussing in context some relevant information from a source outside the assigned sources;
- comparing and contrasting results generated in an assignment with other assignments/ courses/topics in a way that provides a broader understanding than was originally specified;
- invention (and reasonable development) of alternative approaches to achieve the same technological or learning objective specified in the assignment.

4. Needs Improvement

There are two important consequences when a work is assessed as Needs Improvement. **First**, when a work product does **not** meet expectations, a student has **limited opportunity** (for example, a single attempt, due one week after the work is returned) to correct the work product to meet expectations. **Second**, once a work product is assessed as Needs Improvement, it can **never** then be assessed as Exceeds Expectations.

d) A Final Note

Use of this assessment process has made the course faculty keenly aware of the need to have expectations clearly defined **before** the work is attempted; failure to do so leads to 'moving or changing expectations' (real or imagined) and 'moving or changing expectations' demotivate students. As a consequence, considerable effort has been expended to **clearly and completely define expectations for all of the course assignments**.

4. The Need To Participate

All sessions rely, to some extent, on group or team work during the class period. The Laboratory and Modeling Sessions may require or encourage team work outside of class. The success or failure of this learning environment relies, at least partially, on the students' commitment to participating in group or team activities. If the students do not participate in

the team work, their ability to grasp the important concepts of the class is reduced; consequently, students must assume responsibility for participating in group or team work and team assignments.

Fear of failure, frustration, and confusion³¹ are the principal reasons students give up and stop trying. The explicit specifications of the required work products and of the process used to assess these work products minimizes the fear of failure and, to some extent, the confusion. However, some level of frustration and confusion (i.e., a feeling that nothing works or that the material makes no sense no matter how hard they try) is an inevitable part of any class for many engineering students. Some classes have inadvertent frustrations; this class, with its constructivist delivery, has some deliberately built-in frustration. It is hoped that the reflection, or meta-thinking, that is encouraged in the Concepts, Modeling, and Laboratory Sessions will help students deal constructively with the frustration; i.e., allow them to figure out how to solve the problem. Teams can be a tremendous help in reducing the intensity of the frustration and can, in many cases, actually identify solutions that eliminate the frustration; this is one of the principal reasons that team training is conducted in the course. By the end of the semester, it is hoped that the students (and their teams) will be proactively identifying ways to make the course work and how to eliminate or circumvent the frustrations of the class; i.e., the students will begin to demonstrate some of the characteristics of the self-regulated learner.

C. Student Success in ECE 100 and in the Engineering Curriculum

Student success in the freshman engineering course, in the sophomore courses, in the engineering curriculum, and in the practice of engineering has been addressed in the recent literature^{32,33}. The elements of ECE 100 that are essential to student success were derived from these references and from three other sources: (1) *"North Carolina State University Engineering Education as an Ordeal and its Relationship to Women in Engineering"*³⁴, (2) *"Using Cognitive Theories to Improve Teaching"*³⁵, and (3) *"Communicating About the Behavioral Dimensions of Grades"*³⁶. Ensuring, or at least

³¹ "The Confused Student: Five 'Sources of Bewilderment' ", *The Teaching Professor*, February 1996. (Reference : Abigail Lipson, "The Confused Student in Introductory Science." *College Teaching*, 40:3, Summer 1992, pp. 91-95.)

³² Landis, Raymond B., *Studying Engineering: A Road Map to a Rewarding Career*, Discovery Press, Burbank, California., 1995.

³³ Goldberg, David E., *Life Skills and Leadership for Engineers*, McGraw-Hill, 1995.

³⁴ O'Neal, J.B., Jr., "North Carolina State University Engineering Education as an Ordeal and its Relationship to Women in Engineering", American Society for Engineering Education, Proceedings of the ASEE Annual Conference, Edmonton, Alberta, Canada, July 1994.

³⁵ "Using Cognitive Theories to Improve Teaching", *The Teaching Professor*, April 1995. (Reference : Marilla D. Svinicki, "Practical Implications of Cognitive Theories." Reprinted in Kenneth A. Feldman and Michael B. Paulsen, eds., *Teaching and Learning in the College Classroom*. Needham Heights MA: Ginn Press, 1994.)

³⁶ Solomon, Paul, and Annette Nellen, "Communicating About the Behavioral Dimensions of Grades", *The Teaching Professor*, February 1996. (Source : Standards, Assessment and Testing Committee - Dr. Paul Solomon, Chair, College of Business, San Jose State University, April 1995. Adapted from John H. William's, "Clarifying Grade Expectations," *The Teaching Professor*, August/September 1993.)

improving, the student's chances for success have been addressed in **both** the course topics **and** in the management (delivery) of the course.

How the ordeal and the cognitive theories cited above are addressed in ECE 100 is discussed below; an annotated version of the behavioral dimensions of grades is included as well as a discussion of what students should expect from the engineering education process.

1. How the Ordeal has been Addressed in ECE 100

Engineering students are certainly aware that engineering education is an ordeal; the flowchart presented on a following page is not uncommon and certainly provides some anecdotal evidence of their beliefs. The ECE 100 faculty and the Dean's Office of the College of Engineering and Applied Sciences at ASU believe that O'Neal is absolutely correct; engineering education **has always been** and **will continue to be** an ordeal. We also believe that O'Neal has clearly identified a serious problem with engineering education; some engineering faculty, unlike their counterparts in the Marine Corps (i.e., the Drill Instructor), might **not** be involved in, or committed to, the successful completion of the engineering students' ordeal. The ECE 100 faculty, with the encouragement and the assistance of the Dean of Engineering, have explicitly designed ECE 100 to help students successfully complete the ordeal. Furthermore, the ECE 100 faculty are committed to having **all** of the students who enroll in ECE 100 successfully complete the course and prepare themselves for the ordeal. The features of the ECE 100 course, which are intended to address the ordeal, are summarized below.

a) Semester Base Teams and Active Learning

Both cooperative and collaborative learning are used in the course. In a nationally recognized longitudinal research study by Alexander Astin³⁷ at UCLA, two criteria for long term success (i.e., **after** leaving the university) have been clearly identified, one of which is the quality of a student's interaction with other students. There are at least two opportunities to meet this criterion; (1) classes where active learning and student teams are used both inside and outside the classroom and (2) involvement in student activities at the university. Team training for students which includes a foundation in team dynamics and the development of team norms is included in the ECE 100 course as is an introduction to the principles of active learning. Building a sense of community among engineering students is important and the use of student teams contributes to this outcome.

b) Self Regulation³⁸

The importance of individuals assuming personal responsibility for and control of their own acquisition of knowledge and skill is the first of the five explicit objectives of the ECE 100 course discussed above. The behaviors that are essential to successfully completing the ordeal, and their relationship to earning high grades (see the article on the behavioral aspects of grades³⁹ below) are also explicitly addressed in ECE 100. These survival and

³⁷ Astin, Alexander W., *What Matters in College? Four Critical Years Revisited*, Jossey-Bass, 1993.

³⁸ Zimmerman, Barry J., "Self-Regulated Learning and Academic Achievement: An Overview", *Educational Psychologist*, 25, 1990, (1), pp. 3-17.

³⁹ Solomon, Paul, and Annette Nellen, "Communicating About the Behavioral Dimensions of Grades", *The Teaching Professor*, February 1996. (Source : Standards, Assessment and Testing Committee - Dr. Paul

success strategies are consistent with the recent engineering literature on these topics^{40,41}. (Either one, or both, of these textbooks should be considered by engineering students for their professional library.)

c) A General Problem Solving Heuristic⁴²

has been included in ECE 100; it is useful for solving engineering problems; it can also be used to address the problems of the ordeal in particular and life's problems in general.

d) Detailed Specifications

of what is expected of the student in this course are included in the course materials. These specifications and their concomitant checklists are consistent with the quality management principles used extensively in industry today. Expectations for the organization and presentation of technical work are also included in the course materials. This structured approach allows students to determine what level of performance they wish to demonstrate in this course. The ECE 100 faculty recognize each student's right to make this decision based on the workload in their other courses, outside employment, and other life choices; no judgment will be made by the ECE 100 faculty of a student's conscious choice of performance level.

e) More Time is Spent in the Classroom

working with other students. Efforts have been made by the ECE 100 faculty not to exceed a 3/1 rule of thumb for work outside of class. Thus, the 12 hours per week that would normally be spent working outside of class has been reduced to 10 hours per week to accommodate the additional 2 hours per week spent in the classroom. If the student teams function at a nominal level, the work products developed for this class can be completed in the 10 hours per week scheduled for work outside of class. This expectation is based on data excerpted from student work logs for this class.

f) Several Different Communication Mechanisms

have been provided for students to communicate with the instructors **outside** of the classroom; besides office hours, instructors are accessible through email, and a comprehensive World Wide Web site for **ALL** of the class materials is provided. This feature of the class addresses to some degree Astin's⁴³ other criterion for long term success, the quality of the student's interaction with the faculty outside of the classroom. The ECE 100 faculty understand the student's desire for smaller, more informal classes; however, the economic milieu that exists today in all sectors of our society mandates larger, more formal classes. The use of an 'electronic environment' appears to be one mechanism for allowing students and faculty to interact outside of the classroom.

g) The Engineering (or Academic) Journal

has been introduced into ECE 100. This journal is designed to be used for recording, or documenting, **and continuously improving** the student's learning process. It also

Solomon, Chair, College of Business, San Jose State University, April 1995. Adapted from John H. William's, "Clarifying Grade Expectations," *The Teaching Professor*, August/September 1993.)

⁴⁰ Landis, Raymond B., *Studying Engineering: A Road Map to a Rewarding Career*, Discovery Press, Burbank, California, 1995.

⁴¹ Goldberg, David E., *Life Skills and Leadership for Engineers*, McGraw-Hill, 1995.

⁴² Fogler, H. Scott and Steven E. LeBlanc, *Strategies for Creative Problem Solving*, Prentice-Hall, 1995.

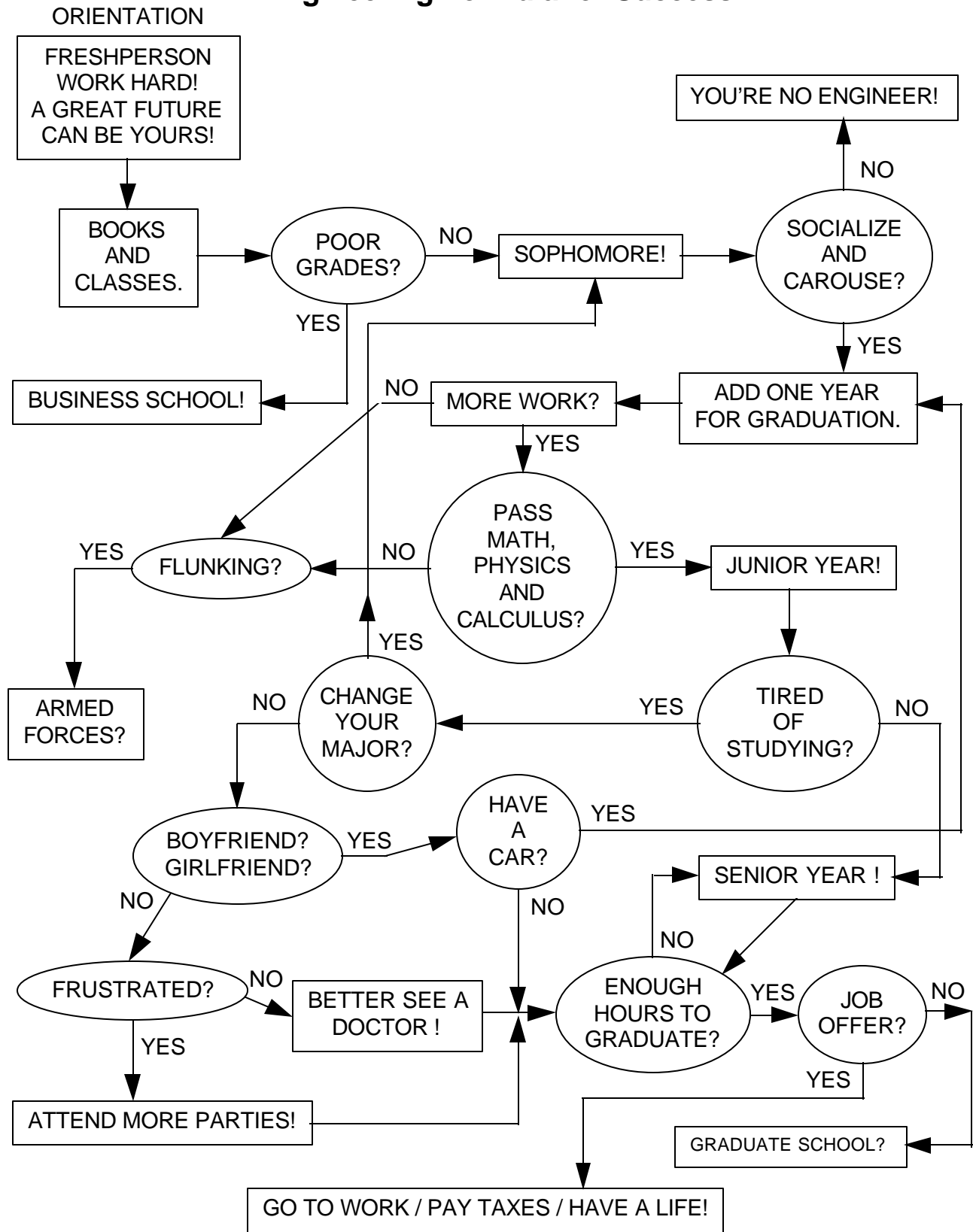
⁴³ Astin, Alexander W., *What Matters in College? Four Critical Years Revisited*, Jossey-Bass, 1993.

provides an additional opportunity for students to reflect on their learning experience through reflecting on their assigned reading. Reflective learning⁴⁴ has been identified as an important facet of becoming an autonomous or life long learner. The 'presentation sandwich' format required for all submitted work products provides another opportunity for reflective learning in ECE 100.

We sincerely hope that the students in ECE 100 recognize and value these features of the course. We also hope they will actively participate in all of the learning experiences in this course and in the continuous improvement of the course.

⁴⁴ Prescott, Susan, *Cooperative Learning and College Teaching*, New Forums Press, Stillwater, Oklahoma 74075, Fall 1996, pp. 10 -11.

Engineering Formula for Success¹



FROM MARK BROWN, TEAM A5, ECE 100 SPRING 1996 : MTU ENGINEERING T-SHIRT, NO VISIBLE COPYRIGHT

Using Cognitive Theories to Improve Teaching (and Learning!)

from *The Teaching Professor*, April 1995

"Learners are **not** simply **passive recipients** of **information**; they **actively construct** their **own understanding**." (p. 275) If you agree, you are ready to consider cognitive theory as the foundation for teaching. Marilla Svinicki elaborates in an excellent article that distills cognitive theories of learning. From this vantage point, The learner is at center stage. The instructor becomes a facilitator of learning, rather than one who delivers the message. ... Cognitive psychology says that the learner plays a critical role in determining what he or she gets out of instruction. (p. 275) Svinicki then draws six principles from cognitive theory that operationally define this perspective, with implications for applying the principles.

Principle 1. If information is to be learned, it must first be recognized as important.

The more attention effectively directed toward what is to be learned, the higher the probability of learning. This begins simply: instructors write key ideas on the board; textbooks highlight the most important points. It becomes more complicated as students within a given major must learn how a discipline determines what is important. They can do that more readily if instructors make those determinations explicit.

In ECE 100 the course goal, learning objectives, and competencies are explicitly stated, as is the ancillary level of learning; the important topics are highlighted in the matrix.

Principle 2. During learning, learners act on information in ways that make it more meaningful. Instructor and students should use examples, images, elaborations, and connections to prior knowledge to make information more meaningful, to bridge from what is known to what is unknown. This makes it very important for instructors to know what kinds of knowledge and experience students bring to the new learning situation.

In ECE 100 active learning in semester base teams allows students to help one another to build these bridges. Pre-assessment of computer skills is used to determine what knowledge and experiences the students bring to this new learning situation.

Principle 3. Learners store information in long-term memory in an organized fashion related to their existing understanding of the world. The instructor can help students organize new information by providing an organizational structure, particularly one with which students are familiar, or by encouraging students to create such structures; in fact, students learn best under the latter condition. Without instructor guidance, students either impose their own structure - most generally a structure that reflects an uninformed view [of] things (and often leads to misconceptions) - or memorize the material minus any structure, which leads to fast forgetting.

In ECE 100 the course goal, learning objectives, competencies, and the ancillary level of learning are specified in the competency matrix. A general problem solving heuristic [see c) above] and an Engineering (or Academic) Journal [see g) above] are also included

Using Cognitive Theories to Improve Teaching (and Learning!)

Principle 4. Learners continually check understanding, which results in refinement and revision of what is retained. Opportunities for checking and diagnosis aid learning. This point underscores a point made in the article from the April 1995 issue of *The Teaching Professor*, "Still More on Student Questions" - the need for instructors to give students time to check on their understanding.

*In ECE 100 the assessment process in Figure 3 above, the use of quality principles [see **d**) above], the Engineering (or Academic) Journal [see **g**) above], additional time in class [see **e**) above], and extended office hours [see **f**) above] are included to address this principle.*

Principle 5. Transfer of learning to new contexts is not automatic, but results from exposure to multiple applications. During learning, provision must be made for later transfer. Svinicki elaborates this way (p. 280): The more (and the more different) situations in which students see a concept applied, the better they will be able to use what they have learned in the future. It will no longer be tied to a single context.

In ECE 100 the material is learned and practiced in three separate contexts or sessions; see Concepts, Laboratory, and Computer Modeling above.

Principle 6. Learning is facilitated when learners are aware of their learning strategies and monitor their use. The instructor should help students learn how to translate these strategies into action at appropriate points in their learning. In other words, the application of cognitive theory implies a responsibility to teach both content and process. Students need to learn how to learn just as much as they need to learn things.

*In ECE 100 the Engineering (or Academic) Journal [see **g**) above], was included to address this principle.*

In summary, Svinicki makes an interesting observation: There is a great deal of intuitive appeal to the cognitive approach to teaching. It echoes our own experience as learners and is easy to understand. Applying the approach is more difficult, however, because we must give up our illusion of control. **That change shakes the foundation of content as the primary focus of our teaching.** We are then faced with the task of adapting to the needs of learners, **a varied and unpredictable group.** (p. 281)

Communicating About the Behavioral Dimensions of Grades
by Paul Solomon and Annette Nellen, San Jose State University

From *The Teaching Professor* February 1996

In *The Teaching Professor* (August/September 1993), John H. Williams of Pepperdine University provided a detailed profile of the characteristic attitudes and behaviors of both the typical A and the typical C students. He used the profiles to explicitly communicate his values and expectations, to help students better understand how their performance would be judged. He believed faculty could use the approach to help students take more responsibility for their own learning.

A faculty committee addressing standards in our College of Business at San Jose State University found this article a valuable source of dialogue last spring. The profiles helped committee members communicate and compare their own grade expectations, in an attempt to establish some uniformity of standards within our college. In our dialogue we elaborated on and created additional behavioral dimensions for the original standards.

We have distributed these dimensions to hundreds of students during orientations and in classes. We have not assessed their impact empirically, but we believe these dimensions benefit our students in the following ways:

- Students learn that not all instructors or institutions have the same standards. Many students assume that the same effort they expended in high school or a community college will earn equally high grades at a university.
- Students clearly discern the professor's concern for them and their success. That is, an unconcerned professor would not go to this length to mentor student success.
- Students see that an A is not reserved for the truly gifted but is a level that a reasonably bright and motivated student can attain. The path to an A is not vague, but the result of behaviors students can consciously adopt to increase their likelihood of success.
- Students learn that communication skills will be used to evaluate their classroom performance. This encourages those students with deficient skills to take active steps to remedy their situation.
- Students perceive that the behaviors are designed to guide them, not to judge them. If they do not have the time it takes for an A, they are encouraged to modify their expectations and work toward a more attainable grade.

The following information is designed to explain what behaviors are likely to earn you an A versus a C. Treat the nine dimensions as guidelines for earning these grades rather than rigid conditions for or guarantees of success. In particular classes, for example, an A student can earn a C while a C student can earn an A. Likewise, an A student may earn an A without satisfying the characteristics of an A student on all nine dimensions. It is very difficult for anyone, no matter how exceptional, to consistently exhibit every quality associated with that of an A student.

Communicating About the Behavioral Dimensions of Grades

'A' or OUTSTANDING PERFORMERS	'C' or AVERAGE PERFORMERS
1. Ability (Talent)	
...have a special aptitude, motivation, or a combination of both. This talent may include either or both creativity and organizational skills.	...vary greatly in aptitude. Some are quite talented but their success is limited by a lack of organizational skills or motivation. Others are motivated but lack special aptitude.
2. Attendance (Commitment)	
... never miss class. Their commitment to the class resembles that of their professor. Attending class is their highest priority.	... periodically miss class and/or are often late. They either place other priorities, such as a job, ahead of class or have illness/ family problems that limit their success.
3. Attitude (Dedication)	
... show initiative. Their desire to excel makes them do more work than is required.	...seldom show initiative. They never do more than required and sometimes do less.
4. Communication Skills	
...write well and speak confidently and clearly. Their communication work is well organized, covers all relevant points, and is easy to listen to / read.	...do not write or speak particularly well. Their thought processes lack organization and clarity. Their written work may require a second reading by the professor to comprehend its meaning.
5. Curiosity	
...are visibly interested during class and display interest in the subject matter through their questions.	...participate in class without enthusiasm, with indifference, or even boredom. They show little, if any, interest in the subject matter.

Communicating About the Behavioral Dimensions of Grades

'A' or OUTSTANDING PERFORMERS	'C' or AVERAGE PERFORMERS
6. Performance	
...obtain the highest scores in the class. They exhibit test-taking skills such as an ability to budget their time and to deal with test anxiety. They often volunteer thoughtful comments and ask interesting questions.	...obtain mediocre or inconsistent scores. They often do not budget their time well on exams and may not deal well with test anxiety. They rarely say much during class discussion and their answers indicate a cursory understanding rather than mastery of material.
Note : Performance is a joint function of a student's native ability and motivation. Punctuality, attendance, attitude, curiosity, effort or time commitment, and preparation all indicate motivation.	
7. Preparation	
...are always prepared for class. They always respond when called on. Their attention to detail sometimes results in catching text or teacher errors.	...are not always prepared for class. They may not have fully completed the assignment, have completed it in a careless manner, or hand in their assignments late.
8. Retention	
...learn concepts rather than memorize details so they are better able to connect past learning with present material.	...memorize details rather than learn concepts. Since they usually cram for tests, they perform relatively better on short quizzes than on more comprehensive tests such as the final exam.
9. Time Commitment (Effort)	
...maintain a fixed study schedule. They regularly prepare for each class no matter what the assignment. They average 3 - 4 hours of study for every hour in class.	...study only under pressure. When no assignment is due, they do not review or study ahead. They average no more than 2 hours of study for every hour in class. They tend to cram for exams.

Source : Standards, Assessment and Testing Committee - Dr. Paul Solomon, Chair, College of Business, San Jose State University, April 1995. Adapted from John H. William's, "Clarifying Grade Expectations," *The Teaching Professor*, August/September 1993.

What Should Students Expect from the 'Engineering Education Process'?

Revised and Redacted Excerpts From

North Carolina State University Engineering Education as an Ordeal

J. B. O'Neal, Jr.⁴⁵

"suffering produces endurance, and endurance produces character
and character is the sole aim of education"

Paul of Tarsus....Herbert Spenser

Abstract

Engineering education contains ordeals⁴⁶ whose origin can be traced to military education from which modern engineering education is derived. Prior to 1955, the ordeal was primarily focused on the laboratory experience; today it is focused on computer applications and design projects⁴⁷. These ordeals have a negative effect on graduation rates. Whereas the educational use of ordeals may be appropriate for military education and might have been appropriate for engineering education prior to about 1950, their value is questionable in a large university where engineering education coexists on the same campuses with other curricula.

Introduction

Low graduation rates, and the perception that the United States has become less competitive in the international arena, have led many educators to believe that engineering and science education should be restructured.⁴⁸ The federal government, through the NSF, has responded by devoting significant resources to facilitate this restructuring. It is the thesis of this paper that one of the paradigms of engineering education that lead to these perceived problems is the use of ordeals in the education process. Any restructuring of engineering education requires an understanding of these ordeals, their history and their purposes. College education in general includes ordeals; however, it is widely recognized that engineering education is much more of an ordeal than other undergraduate curricula.

Although engineering education now coexists with liberal education on the same campuses, it has an entirely different history and tradition, and was established for different reasons. The ordeal⁴⁹ is a tradition in engineering education and is embedded in its history

⁴⁵ J. B. O'Neal, Jr., "North Carolina State University Engineering Education as an Ordeal and its Relationship to Women in Engineering", American Society for Engineering Education, Proceedings of the ASEE Annual Conference, Edmonton, Alberta, Canada, July 1994.

⁴⁶ The word ordeal is used here to mean a severe trial or experience.

⁴⁷ F. A. Kulacki and Evan C. Vlachos, "Down-sizing the Curriculum: A Proposed Baccalaureate Program and Contextual Basis", *Journal of Engineering Education*, Vol. 84, No. 3, July 1995, pp. 225 - 270.

⁴⁸ Jack R. Lohmann, "Myths, Facts and the Future of U. S. Engineering and Science Education", *Engineering Education*, April, 1991, pp. 365-371; also see the references therein.

⁴⁹ The singular is used to designate a process that may contain many individual ordeals as well as to designate a particularly severe trial or experience.

as military training. Engineering education, as we know it today, is derived from an educational process originally developed to teach certain aspects of warfare. Teaching by ordeal is traditionally inherent in this kind of education. Its purpose was to produce a certain kind of character in soldiers so that they could endure the severe trials of warfare. The word "engineer" originally meant a military officer or soldier, a warrior who specialized in the construction of fortifications, the appurtenances of siege warfare, and the various engines of war⁵⁰. Engineering education began as the education for these military engineers and *evolved* into education for civil or civilian purposes. There is a long-standing and vital connection between engineering education, technology, and warfare. From the longbows at Agincourt to the smart bombs in the Gulf war, technology is the source of military success and, therefore, of vital interest to any society which may have enemies. Thus, in some sense, technology is the source of power, freedom, and self determination. Today, as in the late Middle Ages, the engineer is instructed in techniques that are primary in the conduct of warfare.

It is tempting to compare the graduation rates, and educational procedures in engineering curricula with those of other disciplines such as the humanities, the sciences, and the social sciences which only recently have come to occupy the same campuses as engineering in the United States. This is a comparison of two processes that have different traditions and are designed for different outcomes. Harvard, the first American college, was established in 1636 by the Calvinist founders to educate the clergy and children of the elite^{51 52}. The course of study was primarily Latin and Greek, and later Hebrew. These were studied to give the students access to the scriptures and the classics, which were considered to be fundamental in the life of an educated person. On the other hand, engineering education was motivated first by military considerations and later by the need to train working men to design and build the bridges, canals, steam engines, railroads, roads, ships, etc., required for the industrial revolution. Formal engineering education in the U.S. began at West Point in the early 1800s and was derived from military education in France⁵³. These two radically different forms of education began to coexist on the same campuses when the cornerstones of the modern university were laid by the establishment of Cornell in 1869 where "any person can find instruction in any study" and by Johns Hopkins which became the first faculty-centered research university in the United States in 1876⁵⁴. Thus, although engineering education coexists on the same campuses with the humanities, the sciences, and social sciences, it comes from a different tradition and has different goals than other forms of undergraduate education.

⁵⁰ George S. Emmerson, *Engineering Education: a Social History*, Crane, Russak & Co., New York, 1973.

⁵¹ Fredrick Rudolph, *A History of the American Undergraduate Course of Study since 1636*, Jossey-Bass Publishers, 1977.

⁵² Fredrick; Rudolph, *The American College and University: A History*, Vintage Books New York, 1962.

⁵³ George S. Emmerson, *Engineering Education: a Social History*, Crane, Russak & Co., New York, 1973.

⁵⁴ Fredrick; Rudolph, *The American College and University: A History*, Vintage Books New York, 1962.

Description of the Ordeal

"Look to your right, look to your left, only half the people you see will be with us next semester." This statement, deplored by many⁵⁵, is sometimes used by an engineering professor as a way to impress upon the students the imminent ordeal that they are about to experience. It sets the stage for the ordeal -- an important step in the ordeal itself.

The ordeal in engineering education has three primary parts: 1) students are asked to do homework and quiz problems that are often beyond their ability; 2) they receive grades that are generally below their expectations; and 3) they must spend what many consider to be an inordinate amount of time on their studies, laboratories, computer applications, and design projects.

The heuristic, or rule of thumb, for the time a student should expect to spend studying **outside** the classroom for a given course or academic load varies with the institution, the curricula, and the grade the student expects to earn. A typical ratio is **2/1**, which means to earn an '**average**' grade, the student can expect to spend two hours studying each week for each hour spent in class. Therefore, a student with a **12** credit hour academic load should expect to spend a **minimum of 36** hours **per week** on academics to earn an '**average**' grade.

In most **engineering** curricula, the ratio is at **least 3/1** and can be as high as **5/1** in some courses during certain periods of the semester. Thus, a **12** credit hour academic load in **engineering** may require **48 to 72** total hours per week! Note: a **15** credit hour academic load may require **60 to 90** total hours per week. To survive this ordeal, students must develop an effective problem solving heuristic, organize their time, prioritize their work, and be committed to becoming an engineer.

The ordeal is usually administered by faculty who have high standards and challenge students to do their very best. Although this ordeal is often present in many disciplines, engineering education, with its required math and science prerequisites, seems to have perfected the ordeal into an art form. The general public is aware of the difficulty of this study and is often admiring of those who complete it. When the new engineering students arrive on campus other students warn them of the ordeal that will follow. If the university were the military, engineering education would be the **Marines!**

⁵⁵ John A. White, "Competitiveness, Research and Total Quality Management: Strange Bedfellows!", Talk delivered to the Total Quality Forum, Cincinnati, Ohio, August 8, 1991. Also see "An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics and Engineering," a report of the National Advisory Group of Sigma Xi, January, 1989.

The Changing Focus of the Ordeal

Prior to 1955, the ordeal was primarily focused on the laboratory experience. For example, during the 1953-55 period at Colorado State University in Mechanical Engineering, approximately **40%** of the contact hours in the engineering curriculum were spent in the laboratory (i.e., 91.4 hours in the laboratory versus 140.0 hours in the classroom). Only **1.7%** of the contact hours (i.e., **4.0** contact hours) were spent on 'engineering computing' and approximately **86%** of the laboratory time (i.e., **78.7** contact hours) was spent in engineering laboratories. Most of the data collected in these engineering laboratories was processed using a slide rule or by hand and formal reports were often required.

During the 1987-89 period, approximately **17%** of the contact hours were spent in the laboratory (i.e., 28 laboratory hours versus 133 classroom hours); i.e., laboratory contact hours **decreased** by a **factor** of approximately **3.3** and the percentage of the contact hours assigned to laboratory experiences **decreased** by a **factor** of **2.3**. In addition, 75% of the laboratory time (i.e., **21** contact hours) was spent in engineering laboratories while approximately **5%** of the contact hours (i.e., **8** contact hours) were spent on 'engineering computing' and modeling; i.e., contact hours devoted to computing and modeling **increased** by a **factor** of approximately **2.0** and the percentage of the contact hours assigned to computing and modeling **increased** by a **factor** of approximately **3.0**.

There has been a concomitant increase in the emphasis on design content in the engineering curriculum, separate and apart from the increase in emphasis on the use of modern digital computers. Thus, the focus of the ordeal is still present in engineering education; however, the focus has shifted from the laboratory to computing applications and design projects.

The Educational Purposes of Ordeals

The myths which inform us at the deepest level all contain a series of ordeals. The stories of Abraham, Jesus, the Buddha, and Mohammed are stories of individuals who have faced and overcome fundamental ordeals. From Dorothy and her friends in the Wizard of Oz to Ulysses and Tristan, our heroes have faced trials and difficulties. Joseph Campbell⁵⁶ describes all the great hero myths as variations of the basic theme of the hero's journey: the hero leaves home, finds allies, is tested by ordeals, and as a result of overcoming them returns home with wonderful gifts. It is difficult to conceive of an interesting, important story, which does not involve ordeals.

Engineering education has a parallel with the mythic hero's journey. Young people leave home, find allies in the form of other students and faculty to help them in their journey. They face and overcome the ordeals embodied in engineering education, and as a result, learn how to do miraculous things like design airplanes, satellites, and bridges. These talents are brought with them on their return home.

⁵⁶ Joseph Campbell, *The Hero with a Thousand Faces*, Princeton University Press, 1949.

What one learns from the successful completion of an ordeal is widely known but seldom articulated. With the endurance of the ordeal, one learns how to deal with difficulty and failure, to go beyond what one thought possible. A student learns to keep trying when things go wrong. One learns discipline by striving, and failing, and striving again and finally succeeding. Some will learn how to do things that no one else has done. This is not to disparage the learning of facts such as Newton's laws, or procedures such as solving differential equations. These are the intellectual tools of the trade and are vital; however, the persistence, courage, endurance, and confidence learned by confronting the ordeal are an important part of the educational process. Without the ability to overcome ordeals, it is doubtful that the great contributors to our field like Goodyear, Tesla, Heaviside, Armstrong, etc., would have produced very much of lasting value. Without the character traits learned by the ordeal the engineer may be destined to merely copy what others have done. Most of us who teach engineering recognize that something happens in the education process that transcends mere instruction, the learning of facts and procedures. It is the nature of engineering that every successful engineer must do things that were not learned in school. We are prepared for this by the ordeal of engineering education.

If the ordeal is to be successful in *public* education, most students exposed to the ordeal must be strengthened by it. It must lead to their success. In far too many cases the ordeals of engineering education seem to discourage good people from pursuing their chosen field. The ordeals in engineering education lead to too many failures and are much more destructive than they should be.

Engineering Education as an Initiation Rite

Engineering education, especially as it was practiced in the 120 years previous to about 1950, is similar to many initiation rites of ancient societies. Virtually all cultures establish initiation rites that often include the wounding of the initiate and the instruction in the sacred mysteries⁵⁷. The goal of these ancient initiation rites seems to be a spiritual transformation that results from the series of ordeals.

Prior to about 1950, when someone went off to engineering school, they endured the ordeals of engineering education and were introduced to the mysteries of science and engineering. To many without technical training, science and technology are mysteries if not demonic powers. Many have described the mystery and awe associated with technology and compared technology with religion. Henry Adams, an American historian and descendent of two presidents, was awed by the gigantic machines at the Paris exhibition of 1900: "he began to feel the forty-foot dynamos as a moral force, much as the early Christians felt the Cross ... one began to pray to it. Among the thousand symbols of ultimate energy, the dynamo was not so human as some, but it was the most expressive."⁵⁸ Adams describes x-rays as "a revelation of mysterious energy like that of the Cross; they were what, in terms of mediaeval science, were called immediate modes of the divine substance." For modern people unschooled in science or technology, the creation and use of electric and nuclear energy, communications satellites, CAT scans, modern aviation,

⁵⁷ Eliade, Mircea, *The Mysteries of Birth and Rebirth*, Harper & Row, New York, 1975.

⁵⁸ Adams, Henry, *The Education of Henry Adams*, Houghton Mifflin Co., Boston, 1918.

and computers are indeed mysteries. Scientists and engineers are sometimes referred to as priests because they have access to knowledge that the uninitiated cannot understand. Engineers have created a large part of the world which we all experience. In engineering education, then, there is instruction in what to many are the ultimate mysteries of the modern world.

The Ordeal and Graduation Rates

Ordeals in engineering education currently contribute to low graduation rates. This is made worse by the fact that engineering curricula now reside side-by-side with curricula whose programs contain fewer and less intense ordeals. Courses and curricula are listed in the same catalog, engineering students commingle with students in less demanding curricula, and have a convenient way of transferring into less arduous educational programs.

Low graduation rates in engineering education are, in part, due to a **mishandling** of the educational ordeals. Basic training, even in the Marines, is filled with arduous ordeals, but the attrition rate is quite low for two reasons. First, a recruit is not allowed to drop out; to do so incurs serious legal and social consequences. Second, the drill sergeants and their helpers keep very close watch on every individual and **make it their business to ensure that their recruits do what is required to complete the training**. The sergeants often sleep in the same buildings as the recruits, are with them much of the day, and come to know their strengths and weaknesses. Though harsh and demanding, they are also the students' ally in this educational process. In contrast, today's engineering education is structured to permit students to transfer in and out easily, so that the students need not be fully committed when they enter and, when they are discouraged by the ordeals, they can easily transfer out. This "easy out" process is a result of the coexistence of engineering education with other curricula on the same campuses. Unlike basic training, the student can drop a course when difficulty arises. Furthermore, the professors, who are in charge of the ordeals, are often distant from the students. At most large universities, **it is of little consequence to the professors whether the students complete the program**. The professors generally do **not** invest themselves in ensuring that the students complete the ordeals successfully and may, in fact, focus on 'weeding out' students. Note that Wankat, in his book *Teaching Engineering* has found it necessary to add "the punishing" professor to Lowman's 1985 Model of Teaching; the punishing professor is characterized as attacking, sarcastic, disdainful, controlling, and unpredictable⁵⁹. Consequently, engineering faculty are not, in general, the students' ally. **In order for an ordeal to be an appropriate educational experience, almost all students must successfully complete it**. This condition is not met today in engineering education; therefore, ordeals are of questionable value in this process.

The Effectiveness of the Ordeal for "A" Students

In many ancient rites the ordeal is a wound such as having a tooth knocked out. Many students experience the wound of failure; i.e., failure to pass a course, or pass a quiz, or to do as well as expected. The successful initiate seems to be stronger because of the wound. We speculate that A students suffer few or no wounds so the advantages of the

⁵⁹ Wankat, Phillip C., *Teaching Engineering*, McGraw Hill, 1993, p. 4.

wound does not accrue as much to them. Thus, ***students who make below average grades in engineering do engineering work as well as A students***. Perhaps what they have learned from their ordeal has put them on a par with the more intellectually gifted students. This is borne out by the many studies that show ***that grade point average is not correlated with professional success for engineers***⁶⁰. Grades may measure how well a student understands the curriculum but ***not*** what a student has learned from the ordeal. It is reasonable to expect that the severity of the ordeal suffered by a student is inversely proportional to their grade point average.

O'Neal's Conclusions

This paper discusses the practice of using ordeals in engineering education and the origin of this practice in military education from which engineering education was derived. Prior to 1955, the ordeal was primarily focused on the laboratory experience; today it is focused on computer applications and design projects. These ordeals apparently serve an important purpose in military education; however, their use in modern engineering education discourages many students from choosing engineering and leads to abysmal graduation rates for those who do. The general failure of faculty to serve as the student's ally, as well as the coexistence of engineering on the same campuses with curricula which do not contain ordeals, contribute to low graduation rates. Any restructuring of engineering education to improve graduation rates must focus on the destructive effects of these ordeals.

⁶⁰ Goldschmid, Marcel L., "The Training and Professional Success of Engineers: an Empirical Study", *International Journal of Applied Engineering Education*, 1991.

SECTION C

Getting Started (Down the Path to Change)

The slides in Section C are used to introduce the basic concepts of change; they are also used to set the tone and the structure for an active learning classroom. A typical presentation of the entire set of slides lasts about twenty minutes. The agenda shown on the first slide also includes a 30 minute introduction to Active Learning (see Section D).

The first three slides provide an example of the general presentation structure used in ECE 100: (1) an agenda listing topics and times, (2) a brief period spent getting ready for class (i.e., transitioning from previous activities to class activities), (3) an outline of the specific goals for the particular class period. Modified versions of these slides are used at the beginning of every class **before** the specific topic is presented.

The specific topics in this section include the subject of change as well as some tools or techniques that are used in managing an active classroom. The slides about change are especially important to the students in the course since the classroom experience will require a change in most student's participation, study, and work habits. Students are not expected to fully understand or appreciate these slides at the beginning of the semester; however, the students can return to these slides and review these issues during the semester when they are feeling the pressures of change.

More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available through <http://www.asu.edu/courses/ece100/>

Section C

Getting Started (Down The Path to Change)

Today's Class Activities



❖ Before Class Starts

- find a table (area) with no more than five people
- try to find a table at which you know *at most* one person

❖ Contact Before Work (10 minutes)

❖ Getting Started (20 minutes) (On Path Of *Change*)

❖ Active Learning (30 minutes)

- short introductory discussion (10 minutes)
- simple jigsaw (PIGS Face) (20 minutes)

❖ Break (10 minutes)

C- 1

Contact Before Work

❖ What Is It?

Contact before work is the *transition* from the activities associated with *getting to* class to *starting* the actual class *work* for the day

❖ What Do You Do?

Typically you quietly discuss with your colleagues what was on your mind as you came to class or something of particular interest to you that you want to share (“Did you see how ASU whipped up on . . .”)

❖ Today, To Get The Class Started:

- introduce yourselves to your classmates who are seated at your table
- each person tell something they have heard about this class

C- 2

Section C

Getting Started (Down The Path to Change)



The Environment and Goals

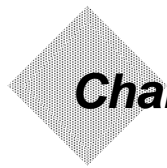
❖ **The Learning Environment**

- active (as opposed to passive)
- group or team based
- workshop facilitators (not lecturers)

❖ **Goals For Today's Class**

- become aware of *change* and the role it will play in this class
- recognize and be able to define some of the major principles of active learning
- practice some active learning

C- 3



Change

As you will soon discover, this course will require you to make at least some ***change*** (and often a big ***change***) in the way you think and react. ***Change*** affects everyone differently; many of you will find these new approaches unusual; a few will perhaps find the approaches disturbing. The next few slides provide a framework for understanding the process of ***change*** and some of it's stages. This material may assist both students and faculty who are finding the ***change*** difficult. Note that students who work through the uncomfortable aspects of the class and actively participate in the classroom experience become productive learners. Furthermore, these students develop, and are able to demonstrate, the skills and abilities that employers are seeking for today's ***changing*** workplace.

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Section C

Getting Started (Down The Path to Change)



Stages of Concern in Change *

- 0 - AWARENESS (I don't know anything about this.)
- 1 - INFORMATION (I've heard a little about this and am actively seeking more information.)
- 2 - PERSONAL (How will this affect my life?)
- 3 - MANAGEMENT (I'm having trouble managing time, materials.)
- 4 - CONSEQUENCES (How is this affecting my customers?)
- 5 - COLLABORATION (I want to work with others who are using this.)
- 6 - REFOCUSING (I can think of some modifications that would make this work even better.)

* Hall, G.E. & Hord, S.M. (1987), Change in Schools: Facilitating the Process, Albany, NY, State University of New York Press

C- 5



Conclusions About Change *

- ① Change is a *process* , **NOT** an event.
- ② *Individuals* , **NOT** organization, change -- *one by one*
- ③ Change is *highly personal* -- each individual sees it in terms of how it affects them and their job.
- ④ Individuals go through phases, or stages, when trying to adopt a change.
- ⑤ Stages can be predicted and planned for.

* Hall, G.E. & Hord, S.M. (1987), Change in Schools: Facilitating the Process, Albany, NY, State University of New York Press

C- 6

Section C

Getting Started (Down The Path to Change)

Cautions About Change *

1. Not everyone in an organization will change,
no matter what !
2. Very few will reach the Refocusing stage.
3. People tend to backslide
when top level attention drifts away.
4. ***IT'S PERFECTLY OK TO BE AT ANY STAGE.***
5. It's OK to move through stages at different rates.

* Hall, G.E. & Hord, S.M. (1987), Change in Schools: Facilitating the Process,
Albany, NY, State University of New York Press

C- 7

'Focus on Facilitator' Signal



The facilitator needs your attention:

- *Raise your hands to inform your neighbors*
- *Finish your sentence*
- *Do NOT finish your paragraph*
- *Turn toward the Facilitator*

C- 8

Section C

Getting Started (Down The Path to Change)

Issue Bin (a useful tool !)

- ❖ Someone will be assigned to be the Issue Bin Collector
- ❖ The following issues will be assigned to the Issue Bin:
 - topics that will or may be addressed later
 - questions that can or should be deferred until the end of the class
 - items that can or should be the subject of future classes
- ❖ Paraphrase the issue and record on the board or a piece of paper which is always visible
- ❖ At the conclusion of the session or class, the issues in the issue bin are brought out, one at a time, and discussed to see if they are still issues.
- ❖ Any issues which remain after the discussion must be addressed in a future class.

C- 9

Code Of Cooperation (Example)

1. EVERY member is responsible for the team's progress and success.
2. Attend all team meetings and be on time.
3. Come prepared.
4. Carry out assignments on schedule.
5. Listen to and show respect for the contributions of other members; be an active listener.
6. CONSTRUCTIVELY criticize *ideas* , not persons.
7. Resolve conflicts constructively.
8. Pay attention, avoid disruptive behavior.
9. Avoid disruptive side conversations.
10. Only one person speaks at a time.
11. Everyone *participates* , no one *dominates*.
12. Be succinct, avoid long anecdotes and examples.
13. No rank in the room.
14. Respect those not present.
15. Ask questions when you do not understand.
16. Attend to your personal comfort needs at any time but minimize team disruption.
17. HAVE FUN !!!
18. ?



Adapted from the Boeing Airplane Group team Member Training Manual

C- 10

Section C

Getting Started (Down The Path to Change)



Process Check

- ❖ Monitoring of processes, especially processes which you own or are a part of, is necessary if improvement is desired
- ❖ A process check is a formalized way to do this monitoring and should be used at the end of all process related activities
- ❖ There are many different ways to conduct a process check
- ❖ A process check must focus on the process
- ❖ Failure of a process does not infer any judgment about the quality of the team members

C- 11



Process Check : Plus / Delta

- ❖ On one 'post-it', place a **+** at the top and write a BRIEF comment below about ONE thing you found valuable and would keep for future sessions.
- ❖ On a second 'post-it', place a **Δ** at the top and write a BRIEF suggestion below about how to improve ONE thing for future sessions.
- ❖ Post the notes in the place designated by the class facilitator when you are finished.

C- 12

The article below from a local newspaper may help place the issue of change in context.

Corporate change: You can count on it

By Julie Amparano Lopez

Staff writer

Arizona Republic, March 3, 1996

AT A GLANCE

PROGRAMS OF CHANGE

In the past 10 years, workers have seen myriad management programs designed to foster change. Here a few of the more popular programs.

- **Restructuring:**
A process for reorganizing businesses or getting rid of unnecessary operations.
- **Down-sizing:**
Scaling back employee ranks to become more efficient.
- **Right-sizing:**
Scaling back outdated or unnecessary jobs to become more efficient.
- **Re-engineering:**
Reorganizing the work process to more effectively create its product or service for customers. Often, layers of jobs are eliminated.
- **Benchmarking:**
A program in which businesses send employees to visit other firms to discover new ways of running a company and handling problems.
- **Empowerment:**
Giving workers authority and power to make decisions that affect their jobs.
- **Total Quality Management:**
Employee teams find ways to improve their own productivity and the quality of their product or service.
- **Broad-banding:**
A system that eliminates multiple salary grades and replaces them with a few to foster more movement among jobs.
- **Skill-based pay:**
Employees earn more for learning new skills that are important to a company.
- **Mission statements:**
Developing goals and purpose for a company or a division.
- **The Learning Organization:**
A program that requires workers to acquire new skills to promote growth and job security.
- **Teams:**
A way of organizing work groups for more efficiency.

The Arizona Public Service Co. mechanic was worn out. Having endured layoffs, a massive re-engineering drive, a painful corporate culture change and subsequent reorganizations, the mechanic had a simple question for the company's top executive at an informal breakfast gathering. "Can you tell us when things will return to normal?" asked the APS employee. "Things have been so hectic for so long." Leaning forward in his seat, APS

Chief Executive Mark DeMichele kindly delivered the news no one wanted to hear: "This is the way things are now. If we want to survive in this business, we have to keep changing."

DeMichele's comment sums up today's world of work: The only thing that's constant is change. As a result, the workplace has become a dizzying and sometimes frightening whirlpool of change. Gone are the days when companies would cautiously tweak their businesses and give workers a year or two to digest the change. Competition, the global marketplace and Wall Street don't tolerate a slow pace anymore.

Corporations now launch several change programs at once in shorter stints - massive restructurings, re-engineering drives, empowerment drives, empowerment programs, team reorganizations, new information systems, diversity and an array of other programs such as skill-based pay and broad-banding.

"Workers don't know which way is up anymore," says Jane Lance, a Nelson O'Connor & Associates consultant who helps workers manage corporate change. "It's really taking a toll on people." "Change is the name of the game," says Scott Jacobson, APS director of strategic change management. The utility is finishing a re-engineering program and culture-change effort that includes re-educating its work force about competition, customer service, and working in a competitive world.

On average, the typical company - such as Honeywell Inc., Motorola Inc. and American West Airlines in the Valley - currently is juggling six to 10 change programs. At APS, there are at least nine change programs moving through the company. Phoenix Newspapers Inc., publisher of *The Arizona Republic* and *The Phoenix Gazette*, is currently handling workplace, management and technology change efforts.

And these companies aren't alone. Most corporations are in the midst of "unprecedented corporate remaking," according to a recent survey conducted by Louis Harris and Associates for A.T. Kearney Inc., a management consulting firm based in Chicago.

Based on interviews with senior executives from 750 corporations, the survey found that every company polled was involved in at least one change program and "anticipates the next few years as a period of turmoil."

About half of the companies said they planned to alter their organization structure, were diversifying their work force and expanding the scope of their business. Nearly three-quarters of those polled said they were revamping their information technology systems and were planning or had started a re-engineering program.

"Monumental change used to hit once or maybe twice a century," says Tomas McIntosh-Fletcher, principal consultant at the McFletcher Corp., a Scottsdale-based research and consulting firm. "Today it's a regular occurrence in most industries."

To witness the impact of change on a company and its workers, consider APS. For generations, the Phoenix-based electric utility was managed through volumes and volumes of manuals. The manuals detailed how every business function should be conducted. There was even a section on how to take a service order. Employees were required to follow the books for everything. And in many respects, the manuals made work comfortable. But "there was no room for creativity, and it was impossible to move quickly," DeMichele reflects. "Another problem was that manuals were written when there was no competition." In 1989, the company realized its way of doing business was antiquated when it became the target of a hostile takeover attempt. To survive in this new world, the company restructured, shedded unwanted operations, got rid of the manuals and developed a new way of doing business. It down-sized, right-sized and restructured again. A new, more competitive way of doing business was introduced. Workers - including DeMichele - were forced to reapply for their jobs and get on board with the new APS.

Now, APS is finishing a re-engineering program and a massive culture-change effort that includes re-educating its work force about competition and customer service, and working in a more competitive world. "This isn't the end. We look at the whole company as a culture in change, and that change is always moving, always on a continuum of change," explains Scott Jacobson, APS director of strategic change management. "Change is the name of the game." All the change, however, has left workers feeling whipsawed. At the same time, the pace of work has become faster than ever before. That's because workers are having to do more now.

Put it all together and corporate corridors are filled with legions of anxious, stressed-out and overworked employees.

Health can suffer

For one manager, the rapidly changing corporate landscape was too much to take. He suffered a nervous breakdown. The manager, who requested anonymity, has weathered two restructurings in his department. Then, he says he was forced to reduce staff.

"It was a very painful period in my life," he said. "It's like our world was turned upside down. It wasn't the place I had joined 15 years ago. I guess I couldn't cope with the changes." After his medical leave, the APS manager opted for early retirement and found a job with a small company. "Life is more sane now. That's what I need in my life right now," he confesses. "I wasn't up to the challenge."

The former APS manager isn't alone in his plight. In fact, most people react poorly to change, according to Rick Allen, president of Next Actions, a management consulting firm in Washington, D.C. "We in corporate America are not very good at change, mainly because we haven't had to change much until recent years," explains Allen. "Therefore, when confronted with a needed change, we may find we don't know how and so we resist." Allen calls it "survivor mode," a condition of non-productive paralysis resulting from increased workloads and continuing uncertainty for workers.

Coping programs added

APS has started dealing with the problems by introducing several coping programs. The company now provides stress-reduction sessions concentration classes and a program that helps employees put their job into perspective. For many, such changes present a whole new way of getting work done. Jacobson, for instance, whirled into his office one late afternoon after spending nearly the entire day in meetings. With only a few hours left in the day, the manager must cram eight hours worth of work into two remaining hours and take the rest home.

But even then, some management consultants wonder whether the trend will make any difference at all. George Bailey, a director at Sit Co., a Princeton, N.J., manager consulting firm, claims change programs haven't been very effective. Based on 4,000 focus groups the firm has conducted over three years, employees and customers rate effectiveness of the management trends at 10 to 20 percent.

Nevertheless, Jacobson thinks companies have to keep trying. "If we don't change, we'll wind up dinosaurs in Jurassic Park."

SECTION D

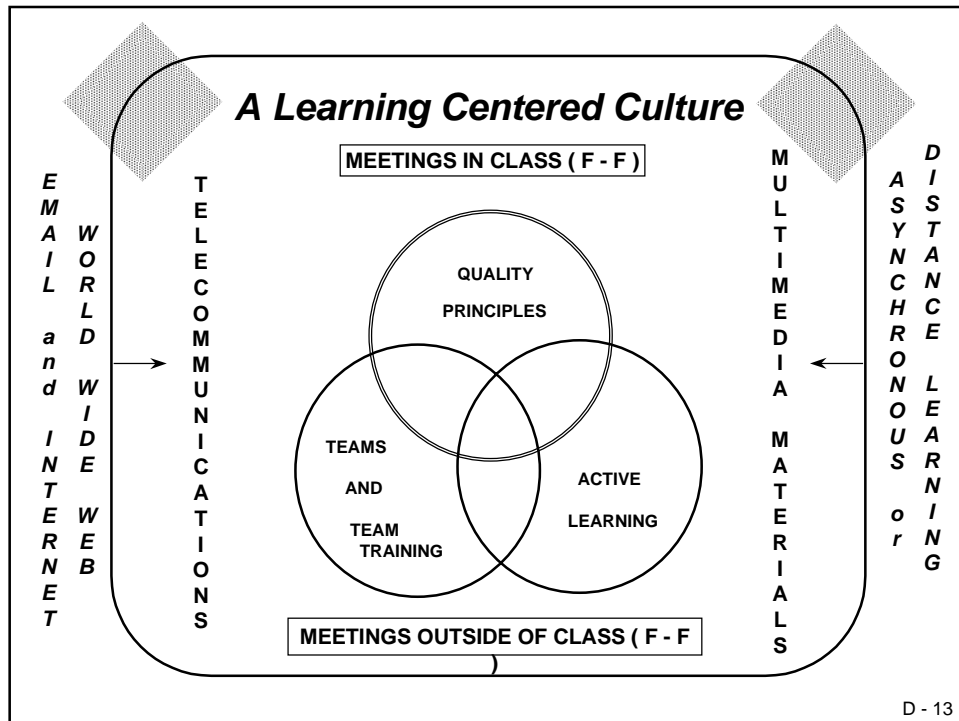
Active Learning

The slides in Section D are used to introduce active learning; the presentation lasts about 40 minutes. A typical presentation includes short lectures, active participation in a simple active learning exercise (i.e., a simple jigsaw), and class discussion. Most presentations will use a subset of these slides; i.e., only a few of the slides will be discussed in detail. These slides are general reference slides that students or faculty might refer to later in the semester. More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.

The specific topics in this section include some tools or techniques that are used in managing an active classroom. One of these tools is the Engineering Journal; **students are encouraged (although not required) to maintain an Engineering Journal during the semester; therefore, this is essential material.** The Engineering Journal is used to encourage reflection, metacognition, and metaprocess; i.e., 'If you don't know **how** you did what you did, you can't improve what you do!'

Section D

Active Learning



Active (Cooperative) Learning

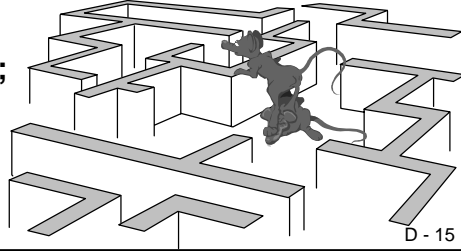
- ❖ A technique used in the classroom which employs student-student and student-facilitator (faculty) interaction in various forms to convert the learning environment from PASSIVE to ACTIVE
- ❖ Enhances learning, if you participate
- ❖ Substantially improves retention, if you participate
- ❖ Increases in value as the material increases in conceptual difficulty
- ❖ Has a long history of success in many different courses

Section D

Active Learning

Teams and Team Training

- ❖ Is used to enhance the performance of a 'group'
(i.e., Group \Rightarrow Team)
- ❖ Applies both INSIDE and OUTSIDE the classroom
- ❖ Applies to both faculty and students
- ❖ Does NOT just happen;
training is required !



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Quality Principles

- ❖ Standardized processes, elementary tools, and a philosophy employed to induce a systemic change in the learning environment
- ❖ Elements include:
 - continuous improvement of the process of education guided by timely feedback from customers
 - criterion-based assessment (e.g., a competency matrix)
 - testing as a feedback mechanism, not as a method for introducing variance
 - *trust rather than fear*
 - cooperation, not competition, at all levels
 - developing intrinsic, not extrinsic motivation
 - an integrated curriculum
 - patience and persistence

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Section D Active Learning

***To Realize the Benefits of a Team Culture
Requires a Change in 'Management Behavior'***

<u>FROM</u>	<u>TO</u>
Directing	Guiding
Competing	Collaborating
Relying on Rules	Focus on the Process
Using Organizational Hierarchy	Using a Network
Consistency/Sameness	Diversity/Flexibility
Secrecy	Openness/Sharing
Passive	Risk Taking
Isolated Decisions	Involvement of Others
People Costs	People Assets
Results Thinking	Process Thinking

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We hold these truths also to be self-evident:

- ❖ Life is for learning.
- ❖ Different people learn differently and have a right to pursue learning in their own style as well as a need to learn the styles of others.
- ❖ Everyone in an educational institution, has something to teach, and something to learn.
- ❖ Life is eclectic.
No one way of teaching, learning, or leading fits all situations.
- ❖ We don't succeed until we all succeed.
- ❖ Diversity is the key to success

Hanson, J. Robert, *Using Authentic Assessment to Meet Performance Standards*, 1994, January 28 - 29, Phoenix, Arizona

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Section D

Active Learning

ASU....THE STUDENT IS ...

- . . . a critical and important member of the University family
- . . . working hard to develop his or her potential to its fullest.
- . . . a flesh and blood human being with feelings and emotions.
- . . . multifaceted - old, young, black, white, red, brown, yellow, male, female, married, single, liberal, conservative, rich, and poor.
- . . . the purpose of our work.

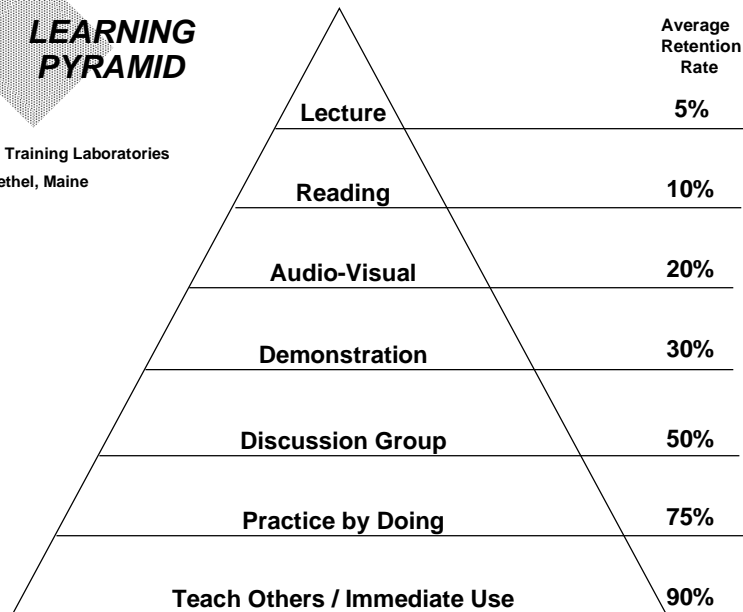
Students pay us a compliment by trusting us to serve them.

A message brought to you by the Associated Students of Arizona State University

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LEARNING PYRAMID

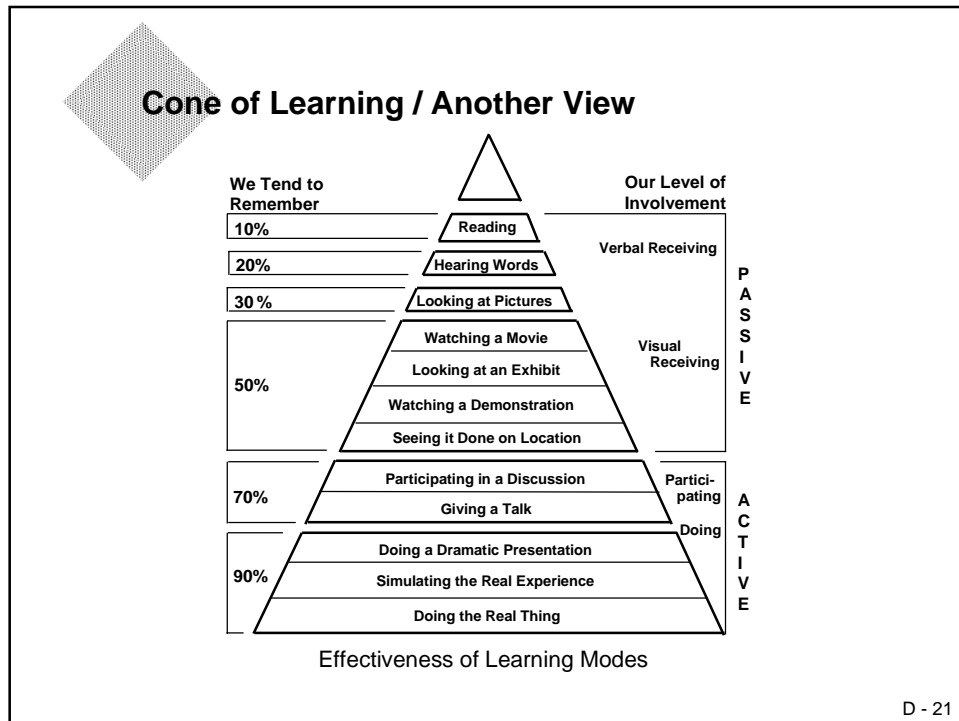
National Training Laboratories
Bethel, Maine



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Section D

Active Learning



Consequences of Teaching and Learning Style Mismatch
(Felder, FIE Meeting, Nashville 1992)

- ❖ **Students:**
 - Become frustrated, bored and inattentive
 - Do poorly on tests
 - Get discouraged about the course, curriculum, themselves
 - Change to another curriculum or drop out
- ❖ **Faculty:**
 - Get defensive or hostile
 - Question their choice of profession; focus on research
- ❖ **Society loses potentially excellent engineers:**
 - visual, active, reflective learners (most students)
 - inductive learners and sensors (experimentalists, plant engineers)
 - global learners (systems thinkers, creative researchers)

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Section D

Active Learning

Consequences ... summary

- ❖ Students may tend toward
 1. *Sensing* or *intuitive* perception
 2. *Visual* or *verbal* input
 3. *Inductive* or *deductive* organization
 4. *Active* or *reflective* processing
 5. *Global* or *sequential* understanding
- ❖ All combinations of types are needed in science and engineering
- ❖ Most of our teaching is *abstract* (*intuitive*), *verbal*, *deductive*, and *sequential*. Students in our classes tend to be passive.
- ❖ To best serve all our students we should be reaching all types, not just one.
- ❖ If we don't, students suffer, we suffer, and society loses valuable contributors.

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*Excerpts from a review of Richard J. Lights' Harvard Assessment Seminars (1990 and 1992 Reports)**

- ❖ "...the single teaching technique that dominates both the 1990 and 1992 reports is the use of small groups
- ❖ Small group work was considered as especially effective for science majors and women
- ❖ and as virtually essential for women in math and science."

*Jim Cooper, *Cooperative Learning and College Teaching*,
Volume 4, Number 1, Fall 1993, page 15

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Section D

Active Learning



Some Cooperative Learning Structures and Procedures (Bits & Pieces)

- ❖ **Think-Pair-Share or Formulate-Share-Listen-Create**
- ❖ **Numbered Heads Together**
- ❖ **Simple Jigsaw and Extended or Complex Jigsaw**
- ❖ **Group Discussion with Talking Chips**
- ❖ **Three Minute Essay**
- ❖ **Structured Controversy**

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Cooperative Learning Bromides (Bits & Pieces)

Contact Before Work
(i.e., provided for some brief exchange between participants)

Begin With the End in Mind
(i.e., specify the objective or competencies of the experience)

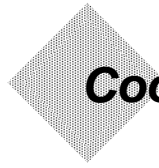
Need to Know Before Knowledge
(i.e., develop an interest in or need to know the material, or competencies, to be realized from the experience)

Structure Before Task
(i.e., communicate the structure or how the task is to be accomplished before commencing the task)

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Section D

Active Learning



Cooperative Learning Bromides (continued)

Balance Process (the How) with Content (the What)

(i.e., during the experience, balance the time and focus on the process as well as on the Content/Task/Product)

Check for Understanding at Critical Points or Times

(e.g., have someone paraphrase the structure, task, or conclusion before proceeding with the next step)

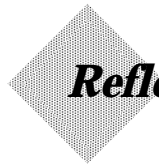
Process Check

(e.g., perform a process check at the end of the experience or at important interim steps using "+ delta", checklists or other forms to obtain timely feedback from the participants)

Reflection

(i.e., pause for brief or even extended periods to think about what you have learned and/or the process used to learn; keep an academic journal of your reflections)

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Reflection (the Engineering Journal)

What is a Journal? A journal is a place to practice writing and thinking. It differs from a diary in that it should not be merely a personal recording of the day's events. It differs from your class notebook in that it should not be merely an objective recording of academic data. Think of your journal rather as a personal record of your educational experience, including this class, other classes, and your current extracurricular life. In ECE 100, formal reflective 'Journal Entries' on assigned course readings are a good way to prepare for quizzes, and will generate pre-quiz 'extra credit' towards quiz grades.

What to Write. Use your personal journal to record personal reactions to class, topics, students, teachers. Make notes to yourself about ideas, theories, concepts, problems. Record your thoughts, feelings, moods, experiences. Use your journal to argue with the ideas and readings in the course and to argue with the instructor, express confusion, and explore possible approaches to problems in the course. Specific instructions for pre-quiz 'Journal Entries' are described elsewhere.

When to Write. Try to write in your personal journal at least three or four times a week (aside from your classroom entries). It is important to develop the habit of using your journal even when you are not in an academic environment. Good ideas, questions, etc. don't always wait for convenient times for you to record them.

How to Write. You should write however you feel like writing. The point is to think on paper without worrying about the mechanics of writing. Use language that expresses your personal voice -- language that comes naturally to you.

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Section D

Active Learning



Reflection

(the Engineering Journal continued)

Suggestions for a Personal Journal:

1. Choose a notebook you are comfortable with; a small (6" x 9") loose-leaf is recommended.
2. Date each entry; include time of day.
3. Don't hesitate to write long entries and develop your thoughts as fully as possible.
4. Use a pen (pencils smear, but are OK if you prefer them).
5. Use a new page for each new entry.
6. Include both "academic" and "personal" entries; mixed or separate as you like.

Interaction -- Professor. the instructor will not read your personal journal. You may wish to include your pre-quiz 'Journal Entries' in your personal journal, or use your personal journal to draft your pre-quiz 'Journal Entries.' The instructor may on occasion, 'argue' with your pre-quiz 'Journal Entries' or comment on your comments. None of this dialogue with you will affect how much your journal is "worth." A good journal will be full of lots of long entries and reflect active, regular use.

Interaction -- Correspondent. Choose a colleague (a fellow student in your group, for example) to read and respond to your journal entries.

Adapted by Karl Smith from Fuller, T. *Teaching with writing.* Portsmouth, NH; Boynton/Cook, 1987.

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Definition:

A Prefix meaning

1. Changed in position or form, altered, transposed
2. Going beyond, higher, transcending

META



Operational Definition:

1. Metacognition : thinking about your thought processes
2. Metaprocess : what process was employed to develop the process



Text Implementation :

Control Heuristics in Problem Solving : constructively criticizing the process used to solve the problem or the model constructed

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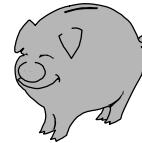
Section D

Active Learning

Essential Elements of Active Learning

- ❖ Positive Interdependence
- ❖ Individual Accountability
- ❖ Group Processing
- ❖ Social Skills
- ❖ Face to Face Interaction

“P I G S Face”



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A Simple Jigsaw Exercise

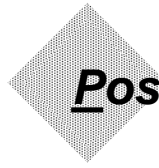
- ❖ Count off in your groups from 1 to 5 (or 6)
- ❖ Depending on your number, (3 minutes)
you will read a paragraph
 - 1's about 6's read about Positive Interdependence
 - 2's read about Individual Accountability
 - 3's read about Group Processing
 - 4's read about Social Skills
 - 5's read about Face to Face Interaction
- ❖ Prepare a 1 minute tutorial on your (5 minutes)
reading to teach your other group
members what you have learned
- ❖ In sequence deliver the tutorials (5 minutes)
- ❖ The Instructor will randomly call on (5 minutes)
you by number for a summary

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Section D

Active Learning

Member Numbers 1 and 6



Positive Interdependence

Positive Interdependence exists when students believe that they are linked with others in a way that one cannot succeed unless the other members of the group succeed (and vice versa).

Students are working together to get the job done. In other words, students must perceive that they “sink or swim together.”

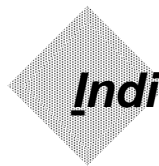
In a problem-solving session, positive interdependence is structured by group members

- (1) agreeing on the answer and solution strategies for each problem (goal interdependence) and
- (2) fulfilling assigned role responsibilities (role interdependence).

Other ways of structuring positive interdependence include having common rewards, being dependent on each other's resources, or a division of labor.

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Member Number 2



Individual Accountability

Individual accountability/Personal Responsibility requires the instructor to ensure that the performance of each individual student is assessed and the results given back to the group and the individual.

The group needs to know who needs more assistance in completing the assignments and group members need to know they cannot “hitch-hike” on the work of others.

Common ways to structure individual accountability include:

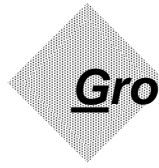
- ❖ giving an individual exam to each student,
- ❖ randomly calling on individual students to present their group's answer,
- ❖ giving an individual oral exam while monitoring group work (e.g., while the individual student is delivering an 'expert' tutorial to a small group).

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Section D

Active Learning

Member Number **3**



Group Processing

Group processing (e.g., process check) involves a group discussion of how well they are achieving their goals and how well they are maintaining effective working relationships among members.

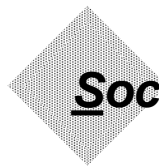
At the end of their working period the groups process their functioning by answering two questions:

- (1) What is something each member did that was helpful for the group and
- (2) What is something each member could do to make the group even better tomorrow?

Such processing: (1) enables learning groups to focus on group maintenance, (2) facilitates the learning of collaborative skills, (3) ensures that members receive feedback on their participation, and (4) reminds students to practice collaborative skills consistently.

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Member Number **4**



Social Skills

Social (collaborative) skills are necessary for effective group functioning.

Students must have and use the needed leadership , decision-making, trust-building, communication, and conflict-management skills.

These skills have to be taught just as purposefully and precisely as academic skills.

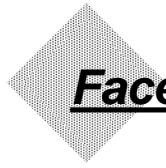
Many students have never worked cooperatively in learning situations and, therefore, lack the needed social skills for doing so.

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Section D

Active Learning

Member Number 5



Face to Face Interaction

Face to face promotive interaction exists among students when students

- orally explain to each other how to solve problems,
- discuss with each other the nature of the concepts and strategies being learned,
- teach their knowledge to classmates, and
- explain to each other the connections between present and past learning.

This face to face interaction is promotive in the sense that students help, assist, encourage , and support each other's efforts to learn.

SECTION E

Quality and Process

Section E introduces the basic concepts of quality. A typical class presentation, which is based on the material in this section, lasts about 100 minutes and includes a mixture of short lectures interspersed with student participation. Quality and what it means is an important topic in ECE 100. Students will want to read this section before class and be prepared to ask clarifying questions. Students should try to fill in the details during the class discussion and may wish to obtain some additional material from the library.

Quality

(revised by Rebecca Dozier and Jennifer McNeill)

Quality is ubiquitous; it pervades all aspects of today's engineering work environment. Employers seek to employ graduates who can work effectively in a quality dominated work environment¹; engineers are expected to use quality processes to create quality products; and, universities are expected to teach students about quality principles. Basic quality principles and tools are presented in this section of the workbook. Some of the material is presented in an *active learning* format; this format requires that you think about a question, and perhaps write down your thoughts, before you read the subsequent paragraph. You will maximize your understanding of the material if you take the time to perform these suggested exercises.

Quality: What Is It?

Take a few minutes and write down your definition of a quality product.



Did you find this hard to do? We certainly did; quality is not easy to define. Does your definition include '*better*' as a descriptor (e.g., the better the product the higher its quality)? Did you define quality in terms of the attributes of the product (e.g., a quality product costs less or goes faster)? How does your definition compare to any of the following definitions:

1. a) Superiority of kind, e.g., an intellect of unquestioned quality. b) Degree or grade of excellence, e.g., yard goods of low quality².
2. Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy implied or stated needs³.
3. The least expensive method of achieving quality is to deliver a design that cannot fail to satisfy the customer⁴.
4. Quality is a measure of customer satisfaction with a product or process⁵.

These are perfectly adequate definitions, but how useful are they? Take a few minutes to consider how you could use any of these definitions (including yours) to establish which of two similar products had the higher quality.



¹ ASEE, "Educating Tomorrow's Engineers", *Prism*, May/June 1995, pp 11-15.

² *The American Heritage Dictionary of the English Language*, Third Edition, licensed from Houghton Mifflin Company. Copyright © 1992 by Houghton Mifflin Company.

³ ANSI/ASQC Standard A3 - 1987, <http://www.cae.wisc.edu/~ming/qlty.html> (visited June 10, 1997).

⁴ Genichi Taguchi.

⁵ A compilation of definitions.

Quality

How did you do? We did not feel our definitions were very operational. The definitions that equate quality to 'better' are meaningless unless you know what 'better' means. Our last three definitions use the concept of 'customer satisfaction'; what exactly is customer satisfaction and how is it measured? The most useful definitions appear to be those that equate quality to a product **attribute**; e.g., low cost. Such definitions apply to particular products; however, there seems to be no attribute, or set of unique attributes, that applies to all products. Consequently, these definitions of quality are not universal. Robert Pirsig notes⁶:

Quality is a characteristic of thought and statement that is recognized by a nonthinking process. Because definitions are a product of rigid, formal thinking, quality cannot be defined. But even though Quality cannot be defined, *you know, what Quality is!*

So which definition is correct? None? All? All the definitions, including yours, are correct for some situations. We like the general nature of the second, third and fourth definitions; however, they all require an understanding of customer needs.

Customer Needs

Assume that you are going to purchase a new video game for the Super Nintendo Entertainment System ® you received for Christmas. Since you are purchasing the game with all the pennies you've saved from working at Burger King ®, you are considered a customer. Make a list of your needs, features that will lead to your satisfaction with the game. For instance, you might need a game that two people can play simultaneously. What other needs do you have?



How long was your list? Did it include the game's graphics, cost, level of difficulty? Categorize the needs you have listed. What categories do you have?

In the mid 1980s Noriaki Kano addressed categorizing customer desires. According to Kano⁷, customer desires (requirements) can be categorized as either an Expected Requirement, a Revealed Requirement, or an Exciting Requirement.

Expected Requirements

Expected requirements are those basic characteristics that customers **assume** are present in generically similar products or services. These characteristics are so basic that the customer seldom mentions them, and all similar products do in fact include these characteristics. For example, one of the **expected** requirements for a video game is that it will have a hard casing around the delicate computer chips. It is **assumed** by the customer

⁶ Pirsig, Robert M., *Zen And The Art Of Motorcycle Maintenance*, ISBN 0-688-00230-7, William Morrow & Company, Inc., New York, 1974.

⁷ Kano, Noriaki, Nobuhiko Seraku, Fumio Takahashi, and Shinichi Tsuji, *Attractive Quality and Must-Be Quality*, Translated by Glenn Mazur, Hinshitsu 14, no. 2, (February, 1984), pp 39-48, Tokyo: Japan Society for Quality Control (see <http://www-personal.engin.umich.edu/~gmazur/tqm/tqm8.htm> for a brief overview by Glenn Mazur [visited June 16, 1997]).

Quality

that all video games have this characteristic and it is unlikely that a customer would mention it to a design engineer. Can you list any other expected requirements?



Did your list include that the game will fit in your Nintendo, have color, have sound, and that you'll be able to control what's happening on the screen?

Revealed Requirements

Revealed requirements are those characteristics that customers discuss when describing the characteristics that would improve a product or service. These characteristics are generally related to the **performance** of the product or service. For example, some **revealed** requirements for the video game would be the game's difficulty level and cost. These are the requirements that are normally discussed with design engineers. Can you list any other revealed requirements?



Did your list include the number of levels, the number of lives you start with, the number of hidden items, and whether or not there's a published hint book?

Compare your list of revealed and expected requirements. Are there any items that appear on both lists? If so, on which list do you now think they belong?

Exciting Requirements

Exciting requirements are those characteristics that cause a customer to say WOW! Generically similar products (e.g., video games) from competing companies will include different exciting requirements. For example, an exciting requirement for a video game would be that it was able to wake you up in the morning. Exciting requirements are only recognized when they are present; thus, they are seldom mentioned to design engineers. Can you list any other exciting requirements?



Did your list include three dimensional graphics, a video game that has a screen saver, or a video game that sounds like you're cleaning your room so that your parents don't get mad at you for not doing your chores.

Review your initial list of requirements and your three new lists. Were there any needs on your first list that didn't show up on any of the new lists? If so, put them on the appropriate list.

Customer Satisfaction

What is the relationship between customer needs and customer satisfaction? Does increasing the number of requirements in each category lead to higher customer satisfaction? Review your categorized lists; would more characteristics in any of the categories increase your satisfaction?.



What did you conclude? Does your satisfaction increase because your game works with your system (expected requirement), or because it takes longer to win (revealed requirement) or has cool 3D graphics (exciting requirement)? How do your results compare with those proposed by Kano (see Table 1)?

Requirement Type	Not Present	Present	More
Expected	dissatisfaction	unaware	no effect
Revealed	dissatisfaction	satisfaction	increased satisfaction
Exciting	unaware	satisfaction	increased satisfaction
Table 1 - Relationship Between Customer Needs and Satisfaction			

Table 1 illustrates that 'more' is 'better' only for the **revealed** and **exciting** requirements; more of an **expected** requirement has no impact on satisfaction (is this true for the expected requirements in your list?). Table 1 also illustrates that there are two ways to produce dissatisfied customers: **omitting expected** requirements and/or including a **minimum** number of a **revealed** requirements. Absence of exciting requirements does not lead to dissatisfaction. Look at your list of requirements to confirm these observations.

Identifying Customer Needs

If quality products are those that satisfy customers, how are these customer needs identified? Did asking you to write down your needs as a video game customer work well? Do you feel your list is complete? Probably not, but why? Only the **revealed** requirements are characteristics that customers think of prior to obtaining or using a product or service. Generally, customers are unaware of expected and exciting requirements; therefore, asking the customer what she wants seldom produces a satisfied customer. Furthermore, it is difficult for customers to evaluate an exciting requirement until they actually see or experience the product. For example, market surveys in the early 1970s suggested that there was no market for engineering hand held calculators.

Quality

Establishing a good set of customer needs is one of the important tasks that must be performed during the Problem Definition Stage of the Problem Solving Heuristic⁸. What are some alternative ways of identifying expected and/or exciting requirements?

The assessment process and the checklists used to evaluate your work products in ECE 100 are discussed in Sections B and J (Part III) of this workbook. Are these checklists *expected*, *revealed*, or *exciting* customer requirements?

A Quality Culture

Do you recognize the name Dr. W Edwards Deming? What word or phrase would you associate with Deming? If you do not recognize, or have only a passing familiarity with, the name Deming, you should spend some time on the WEB and seek out more information.

Deming defined a way of thinking about quality and summarized his philosophy in a set of fourteen points (Figure 1). Deming's fourteen points work together to create a quality 'culture'. The items on the list are not intended to be used selectively; all fourteen points must be implemented as a total 'package'. The ECE 100 course was designed to implement Deming's fourteen points in the classroom.

Read the points. Which of the points do you instantly agree with, which do you not understand, which do you think would be the hardest for you to implement?

1. Create constancy of purpose
2. Adopt the new philosophy
3. Cease dependence on inspection to achieve quality
4. End the practice of awarding business on the basis of price tag
5. Constantly improve the system of production and service
6. Institute training on the job
7. Institute leadership
8. Drive out fear
9. Break down barriers between departments
10. Eliminate slogans and exhortations
11. Eliminate quotas and management by objective
12. Remove barriers that rob people of their pride of workmanship
13. Institute a vigorous program of education and self-improvement
14. Put everybody to work to accomplish the transformation

Figure 1- Deming's Fourteen Points⁹

⁸ Fogler, H. Scott, LeBlanc, Steven E. *Strategies for Creative Problem Solving*, ISBN 0-13-179318-7, Prentice Hall PTR, 1994.

⁹ Deming, W. Edwards, *Out Of The Crisis*, Published by the Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, MA 02139, 1986. (For a summary of the 14 Points see <http://deming.eng.clemson.edu/pub/den/files/auth14.txt> [visited June 10, 1997]).

Improving Quality

There are two methods that can be used to bring about a change in the quality of a product: Re-engineering (*Ishinsuru*) and Continuous Improvement (*Kaizen*). Figure 2 highlights the differences in these two methods; what do you think is the major difference in the two methods? **Re-engineering** involves **major changes** (quantum leaps, radical new designs); a shift in paradigm is often involved. **Continuous improvement**, on the other hand, involves a **steady, continuous change** in quality (small steps, restructuring); paradigm shifts are not involved.

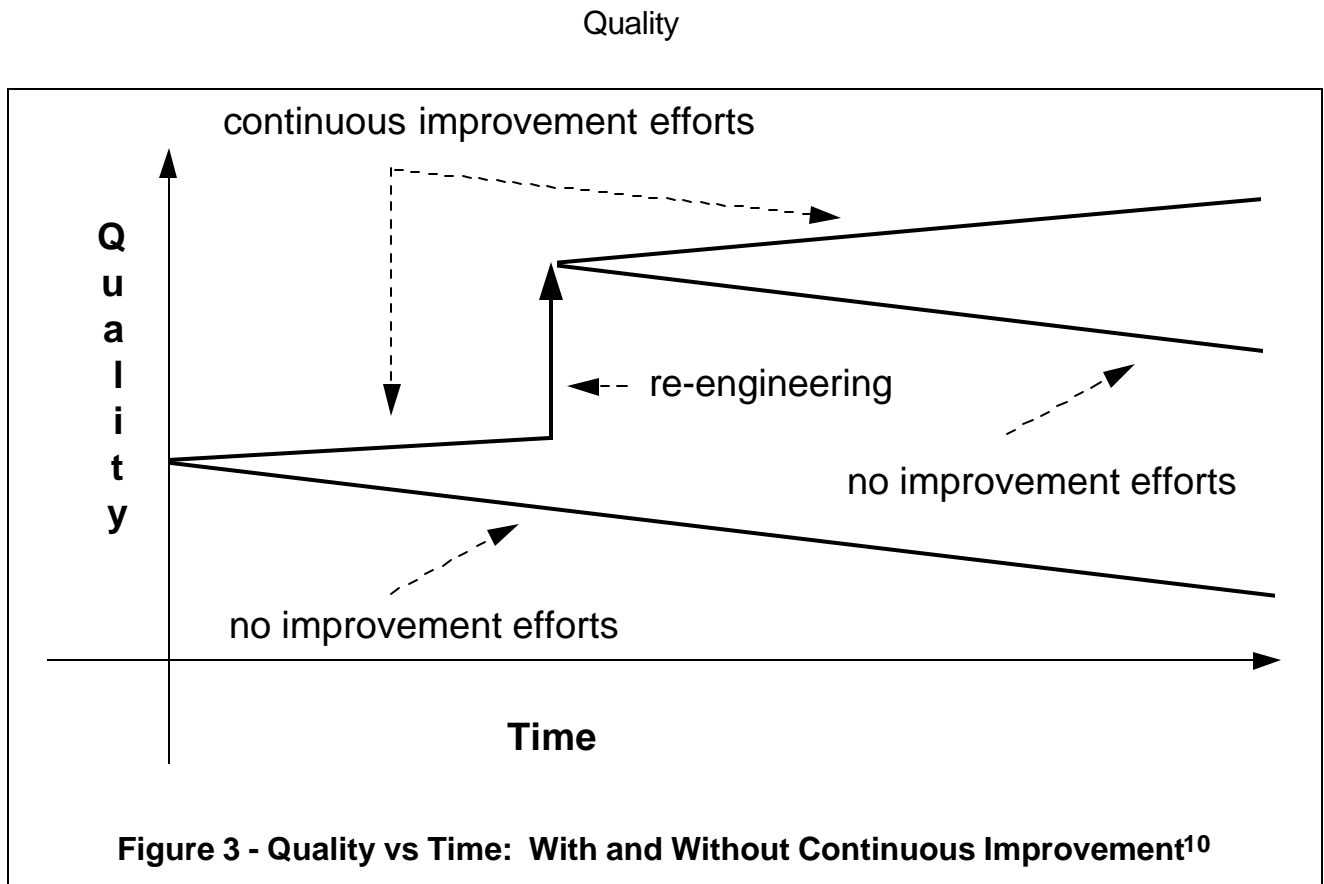
Figure 3 shows how these two process can work together: the bottom line shows that a product's quality steadily declines without a concerted effort to improve it's quality. The

• Continuous Improvement (Kaizen)	• Re-Engineering (Ishinsuru)
<ul style="list-style-type: none"> • Continuous incremental improvement • Small steps • Restructuring • Team work • Customer focused • Sequential processing • Push down decision making 	<ul style="list-style-type: none"> • Quantum leaps • Revolutionary thinking • Radical new designs • Team work • Customer focused • Whole process responsibility • Push down decision making
Figure 2 - Comparison of Quality Improvement Methods	

Kaizen method reverses this trend by **continually** improving the quality (shown by the slightly upward sloping lines). Using *Kaizen* can reverse the natural quality decay; however, it will seldom lead to radical new ideas (changes in quality). When *Ishinsuru* is used there is a **step increase** in quality. Note that if *Kaizen* is not used after the *Ishinsuru* change then the quality will begin its natural decaying process. Can you think of how quality was improved by *Kaizen* and by *Ishinsuru* for the video game?



For *Kaizen*, did you consider the gradual increase in the quality of graphics and sound used in video games or the increase in the sensitivity of player control? For *Ishinsuru*, did you consider the development of systems intended exclusively to play video games from the systems (i.e., personal computers) where video games made up only a portion of the functions?



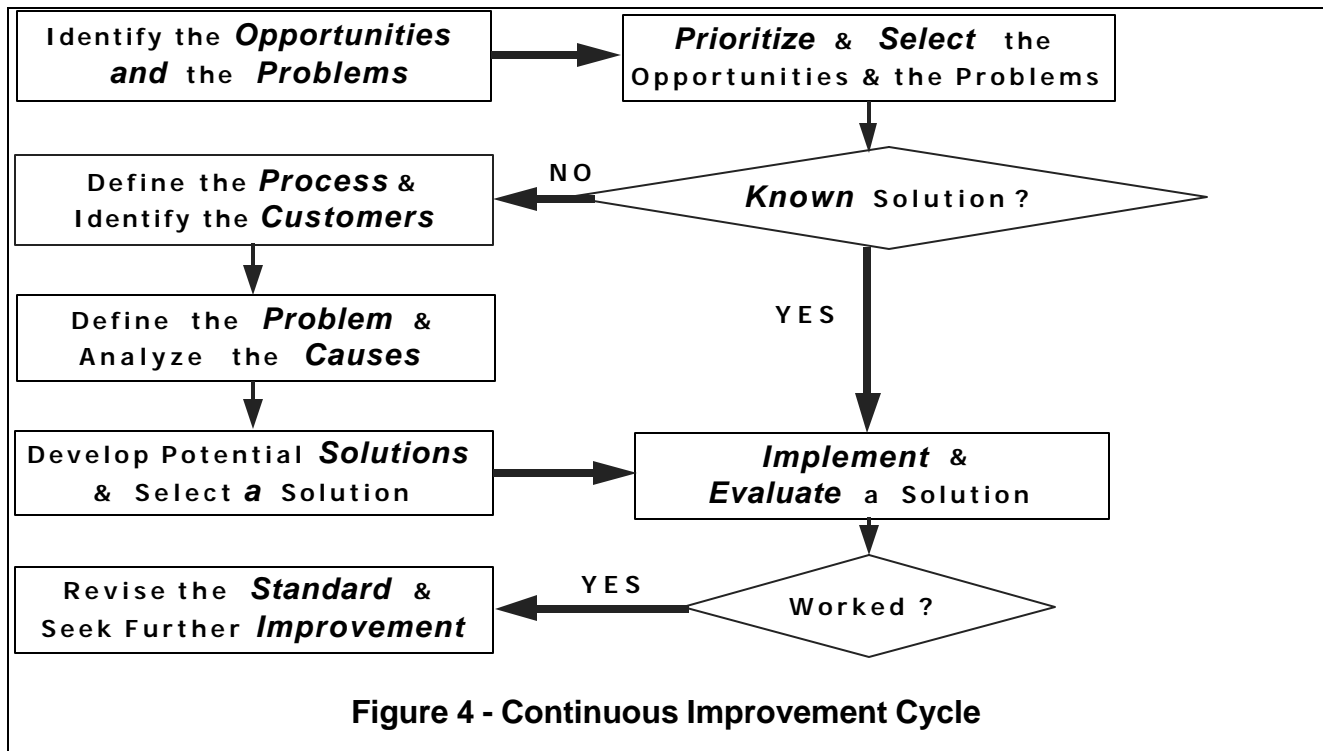
Re-engineering (*Ishinsuru*)

Re-engineering is sometimes defined by its three R's: Rethink, Redesign, Retool. Rethinking is the 'paradigm busting' aspect of the process, creating new visions and defining critical success factors. After a new vision is created new products, processes, and/or services are designed, which are followed by the creation of new jobs and manufacturing processes.

Continuous Improvement (*Kaizen*)

Figure 4 illustrates a typical continuous improvement cycle. The process is initiated by identifying and selecting a problem. If solutions to the problem are known, they are implemented and evaluated; if solutions are unknown solutions must be created (a multi-step process). The process cycle ends with an evaluation of the solution, i.e., did the solution work. If the solution did not work, what would you do next?

¹⁰ Imai, Masaaki, *Kaizen*, McGraw Hill Publishing Co., 1986, pp 27

**Plan**

- define the process
- identify the real problem (collect data to confirm)
- typically 50% of the time is spent on this part of the cycle

Do

- generate and select a solution
- implement the proposed improvement
- typically 10% of the time is spent on this part of the cycle

Check

- measure the effect of the change
- typically 15% of the time is spent on this part of the cycle

Act

- standardize the change
- document the project
- typically 25% of the time is spent on this part of the cycle

Figure 5 - Plan Do Check Act Cycle

Quality

Continuous improvement cycles are often called Plan Do Check Act (PDCA) cycles. Continuous improvement comes from repeated execution of the PDCA cycle. Figure 5 briefly summarizes the steps in the PDCA cycle. 1) **Plan**: this step involves the collection of data to support the selection of the problem and is generally the most time consuming step. 2) **Do**: this step involves the generation and implementation of a solution, and is generally less time consuming. 3) **Check**: this is a critical step. PDCA cycles require that the solution be evaluated, using collected data, to determine if the process, product or service was actually improved, i.e., it can not be **assumed** that the solution improved the process. 4) **Act**: this step involves institutionalizing (standardizing) and documenting the change. Note that one quarter of the effort goes into this step.

Process

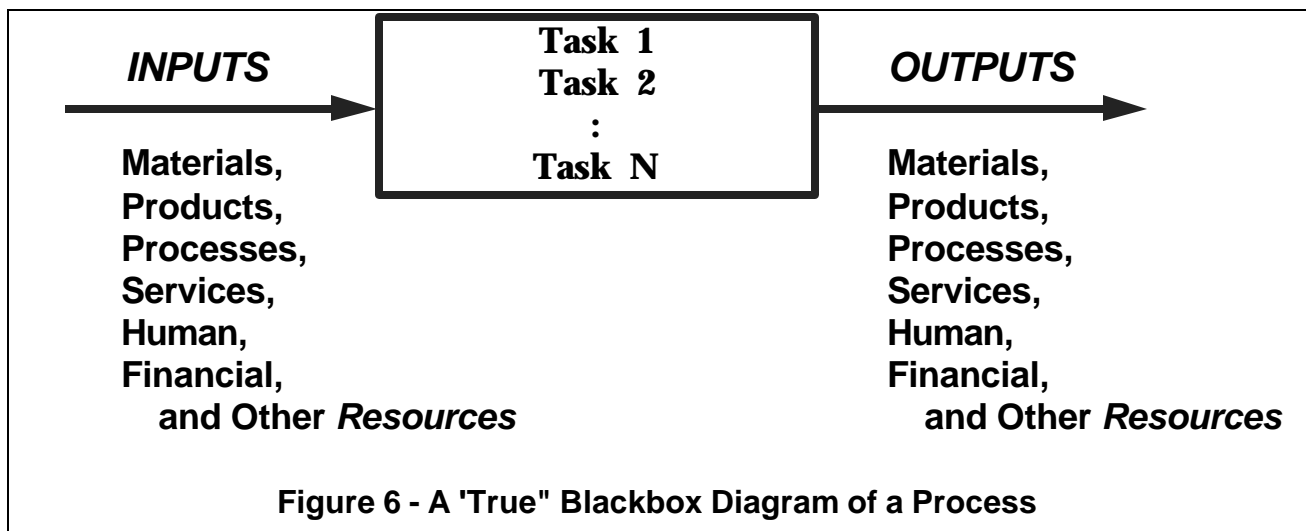
Process is a very important aspect of quality. Take a few minutes and write down your definition of process.



Does your definition address the making of something (e.g., a process is the way something is done)? Did you use an analogy (e.g., a process is like a recipe for making apple pie)? Does your definition include the fact that there are multiple steps or tasks in a process (e.g., a process is a collection of steps used to make something)? Was there any sense of order or organization in your definition (e.g., a process is a sequential set of tasks used to make something). All of these items are important aspects of a process. Our definition, which includes all of the above, is:

A process is an organized collection of interrelated tasks that converts 'inputs' into desired 'outputs'

Figure 6 is a 'blackbox' description of a process. Inputs are converted (changed) into desired (not unexpected or unwanted) outputs. This transformation takes place through the completion of a number of interrelated tasks.



Flowcharts

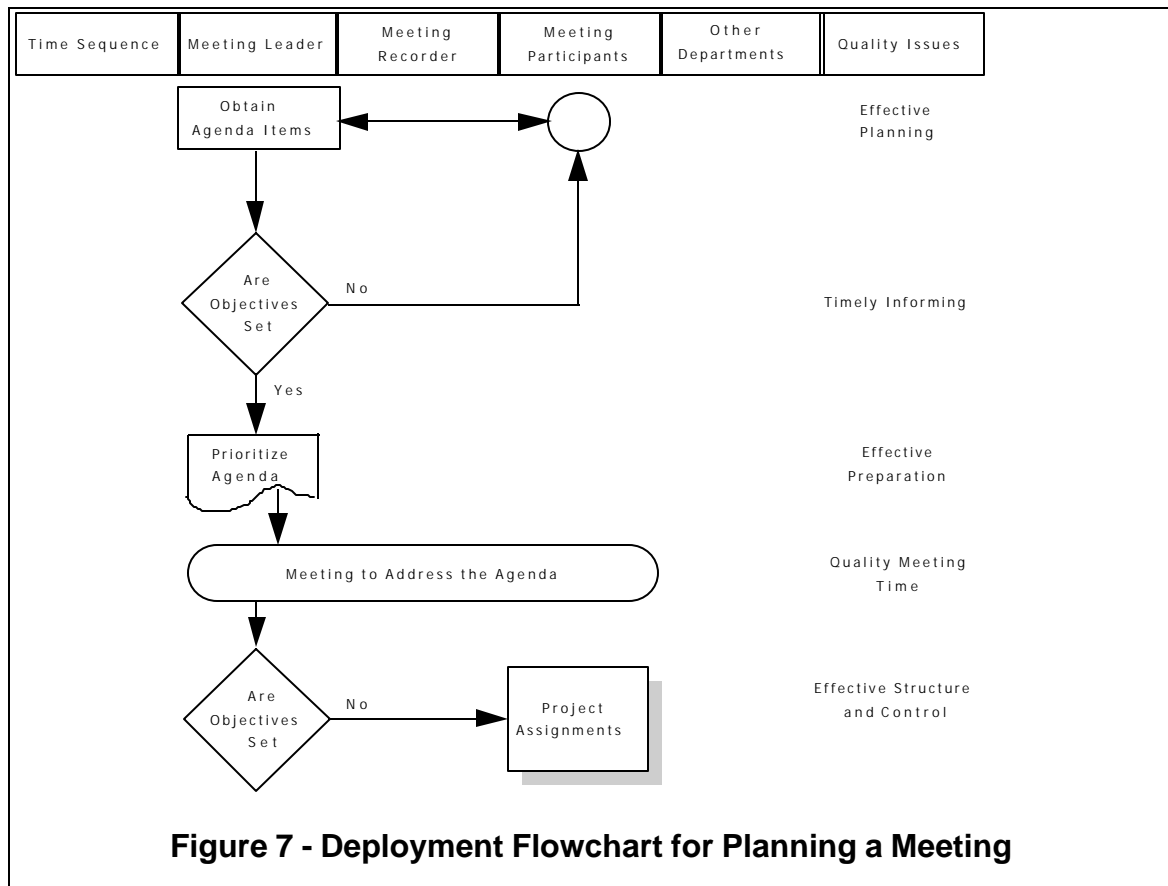
Processes are complex and often hard to describe with words. Thus, processes are generally described using a visual representation called a flowchart. Flowcharts show the various tasks and the relationships among the tasks. There are two general types of flowcharts, process flowcharts and deployment flowcharts:

A **process flowchart** is a chart (picture) that uses symbols to describe the tasks and decisions and lines to describe the interrelationships among the tasks and decisions required to convert available inputs into desired outputs for a specific process

and

A **deployment flowchart** is a process flowchart that also includes: 1) the people responsible for completing the tasks and making the decisions, 2) the time required to complete each task, and 3) the quality issues associated with each task.

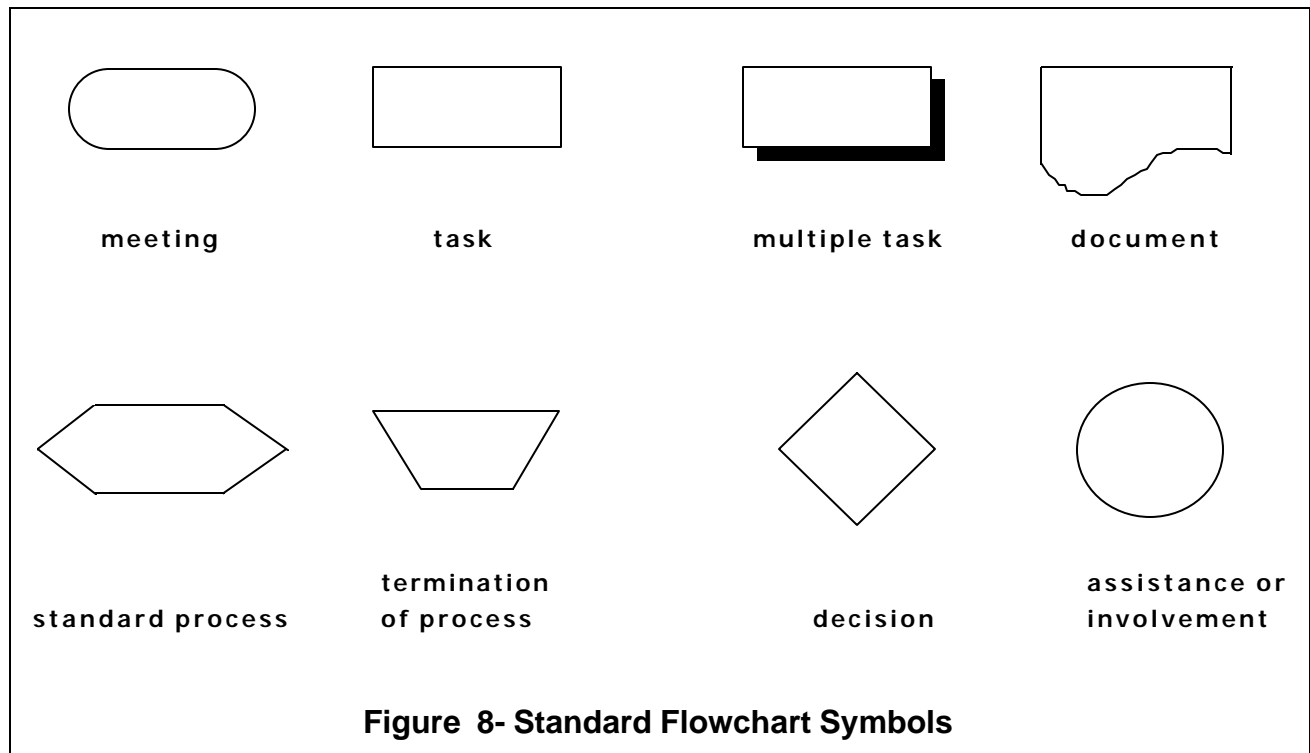
Several example flowcharts are included in this Workbook. What type of flowchart is Figure 3 in Section B? If you said “deployment flowchart” that is correct. Why? If you said “because the figure is a process flowchart (symbols for tasks and decisions, lines for interrelationships) and it shows 1) the responsibilities of three groups of people involved in the process”, and 2) the time involved, and 3) the quality issues, then you answered completely. Figure 7 is another example of a deployment flow chart. Who are the people involved in planning a meeting; what are their responsibilities?



Creating Deployment Flowcharts

The process used to create deployment flowcharts is summarized below.

1. Identify and name the process.
2. Determine the start and finish points of the current process.
3. List the steps involved between the start and the finish using verbs and nouns.
 - a) Brainstorm macro (large) steps (write on post-its, one step per post-it).
 - b) Sequence the steps (move post-its around).
 - c) Brainstorm smaller steps (write on post-its, one step per post-it).
 - d) Sequence and integrate the smaller steps into macro steps.
4. Assign symbols (see Figure 8) to the appropriate tasks and decisions.
5. Divide a blank chart into columns; one column for each key person or group responsible for completion of a task in the process. Draw the chart using the symbols.
6. Identify the control points (i.e., locations in the flowchart where something can be counted or evaluated).



Quality

Can you create a flow chart for playing a Nintendo game?

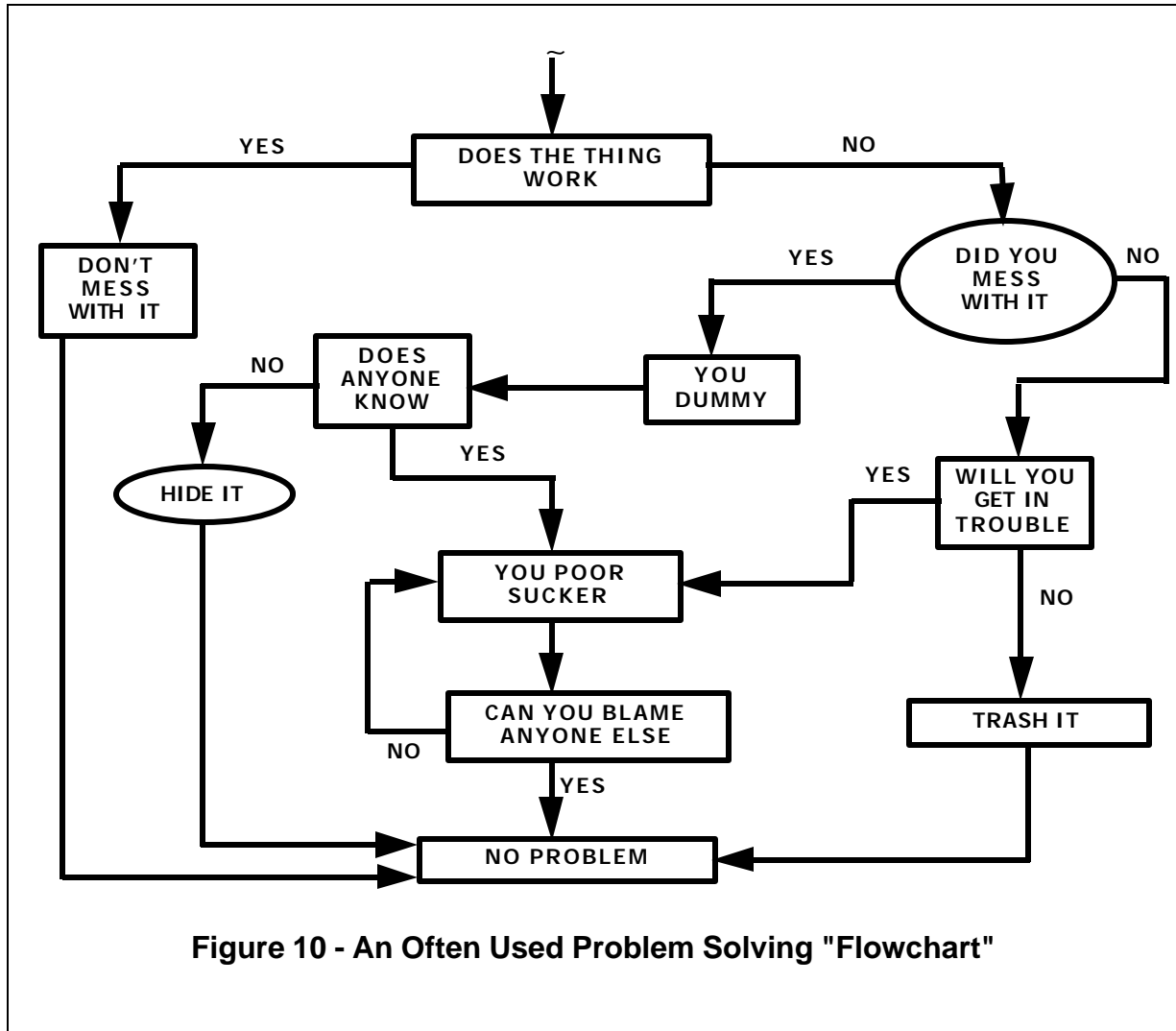


Figure 9 illustrates our suggestion as to what a flowchart for setting up a Nintendo game might look like. Did you come up with something similar?

Can you think of other examples of flowcharts that you have seen. What type of flowchart is the cynically humorous example in Figure 10. Can you analyze this flowchart?



Did you notice that the flowchart in Figure 10 does not use the correct symbols? Which boxes should be replaced with diamonds? What about the symbol terminating the process? Is there anything else wrong with this flowchart? What about the process itself? Do you think that the flowchart presents an ethical approach to problem solving? We think not. In a **quality** environment employers and employees focus on **identifying** and **fixing** problems, rather than focusing on blame. Continuous Improvement, which is the essence of **quality**, requires that problems be identified, brought out in the open (i.e., problems are not hidden), and analyzed to see how the problem can be eliminated. While this flowchart may represent the way some businesses are run, we can predict that in the long run these businesses will not succeed.



The following article from a local newspaper illustrates the importance of quality in the engineering workplace.

Concept creates team players : For AlliedSignal, proof is in figures

By Ed Foster Staff Writer

Arizona Republic, June 28, 1996

In recent months, Dino Clark has seen the time and manpower that goes into producing jet-engine fan hubs drop drastically at AlliedSignal's aircraft engine-parts plant here. Clark doesn't like the word *kaizen*, or continuous improvement, the theory the company is using. Neither does he care for Japanese consultants. For the past 1 1/2 years, two consulting firms associated with Toyota have worked with AlliedSignal factory teams, implementing kaizen. But Clark is enthusiastic about the manufacturing improvements in his machining cell. "I've been here 24 years," Clark said. "We tried different concepts. We could never put the people

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together, the machinery together. "Now we've got everybody, from the president all the way down, working together. They really work with you. Everybody's got a chance to make it work."

Since late 1994, the company has paired teams of workers in various factory areas with outside consultants. The consultants, whose firms have relationships with Toyota, considered a model manufacturer, push the team members toward high goals, and the workers find ways to cut waste to get there. Clark's area, which machines the center hub of the front fan on jet engines, formerly produced fewer than two hubs per day. After being studied and improved, production rose to eight hubs per day. Meanwhile, the number of machine operators dropped from 14 to Six. The time required to set up the machines was 10-15 hours. Through *kaizen*, the machinists got that down to six hours, then three and now 1 1/2h in most cases. Some machines now are being set up in 30 minutes, and the consultants are pushing for 10 minutes.

Clark is enthusiastic about the improvements, but he complains that the Japanese want too much. They have "a lot to learn about reality and life itself," Clark said. Not all the factory workers are as positive as Clark. Some, such as Sherry Brightwell, are far more skeptical. But even Brightwell says *kaizen* has worked, if not as well as management believes. "They have taken out a lot of wasted steps," she said.

Kaizen is being driven by Marc Hoffman, vice president of operations, who came to AlliedSignal in 1994 from one of the consulting companies. Before that, he was a plant manager for General Electric. The effort has been implemented in aircraft-engine factories here and in Connecticut, South Carolina and Ireland. According to Hoffman and his director of operations, Rich Barlow, improvements have been substantial.

Production at the parts plant, which is on the edge of Phoenix Sky Harbor International Airport, **has improved 20 percent** in the past 18 months, Barlow said. "The way we measure is output per human being," he said. "We are getting more widgets from the same people."

Typically, the consultants come in for a week to focus on a particular area. Workers from that area form a team to help find waste and root it out. Barlow said the kind of production gains made in Clark's cell have enabled the engines division to exceed a corporate demand for 6 percent annual production growth easily. Hoffman, 40, said an important key in the improvements has been just-in-time production. Historically, AlliedSignal has produced parts in batches, which sit until they are needed at the next step. Just-in-time production requires that parts be produced as they are needed for the next step.

Hoffman compared it to a bucket brigade. "Problems rise to the surface, and you are forced to address them immediately," he said. The result is reduced inventory and costs, and improved delivery, Hoffman added. He said the factory workers were skeptical when he arrived in 1994. He came from TBM, a North Carolina consulting firm and one of the companies he uses today.

One of his problems has been the word *kaizen*. "If I had to do it over, I might not have used it," Hoffman said. But he made no apology for using outside consultants. Because they don't have friends or an emotional investment in the plant, they are perfectly willing to push wholesale changes. "There is value to not being concerned about hurt feelings," Hoffman said, adding that the consultants bring in a wealth of experience. "They know it is achievable," he said. "They fundamentally believe it can happen."

One technique is videotaping operations, so workers can see waste. "It is almost embarrassing," Hoffman said. AlliedSignal is also passing along its lessons to its suppliers. AlliedSignal teams recently visited Stolper-Fabralloy Co. in Phoenix to help it streamline its

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operations. Mark Russell, quality assurance manager for Stolper-Fabralloy, said the company expects a \$54,000 saving from the two-day session. "We consider it (the training) a great privilege," he added. "They don't do this for all of their vendors." Stolper-Fabralloy makes sheet-metal parts for AlliedSignal engines.

Most of the theories for improvement have been lifted from Toyota and some American companies, including Motorola and Texas Instruments, but Hoffman said they are really just extensions of Henry Ford's ideas. But American industry lost its way and discounted Ford's ideas, he said, especially after World War II, when U.S. industry had little competition and huge markets. "In my opinion, it was arrogance. I remember when I was in college, all the excuses while we were getting the hell beaten out of us," said Hoffman, a 1978 graduate of Cornell University. "Things didn't change because they didn't need to change."

Today, he said, AlliedSignal's customers, aircraft manufacturers and the airlines, demand higher quality and lower prices. The challenge AlliedSignal and other manufacturers face is simple, Hoffman said: Get better or die. "It is not just Boeing. It is every market we are in. Those who fail to improve cannot survive." He added that the increased **efficiency has** not led to layoffs. Instead, the company has been able to use its quality gains and lower costs to snare more business. "The whole idea of improving by laying off people doesn't make good sense," said Hoffman, who said the company must instead leverage its people and factory space to grow.

AlliedSignal has had huge layoffs in the past. The company shed thousands of workers earlier in the decade, after both the civilian and military aircraft markets collapsed. The scars remain. Workers interviewed on the factory floor invariably brought up the possibility of layoffs. Where, they asked, will the people displaced in *kaizen* go? So far, they have been absorbed in new production, as the business has grown. But people such as machinist Charlie Gilchrist, who is cautiously enthusiastic about the changes, believe that could change. "Everybody is scared they could lose their jobs," Gilchrist said. "That has been around since the beginning of *kaizen*. "I don't believe anybody can guarantee me a job these days."

Barlow said employees have been promised that no layoffs will result from *kaizen*. But he said the company can't make promises about recessions. However, he added that as costs continue to decline, work that is now outsourced can be done in company factories. "We only make a quarter of our parts," he said. "As we become more competitive with small parts, we can bring business in from the mom-and-pop shops." Ultimately, the workers on the floor appeared to agree that lower costs could translate to job security in the next recession. "Nobody likes change," Gilchrist said. "But it's coming, and you can't stop it. There's no sense fighting it." At least, he said, management now is willing to listen to the workers, and to tap their expertise. "It opens up communication tremendously," Gilchrist said. "They listen 200 percent better than they used to."

SECTION F

Introduction to Teams

The slides in this section are used to introduce teams; i.e., what they are and why they are important. This material is typically presented as a short lecture which lasts about 15 minutes; it is used primarily as the introduction to the active learning jigsaw exercise on Team Dynamics (see Section G). More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.

A local newspaper article summarizing new research on the 'survival of the nicest' (i.e., as opposed to 'survival of the fittest') is also included in this section.

Introduction to Teams

What is a team anyway?

Take a few moments and write down some examples of teams. While you are doing this, list features that would distinguish a team from an ordinary group of people.



Most people have encountered teams in various forms - whether as amateur or professional sports teams, the 'sales team' at a local car dealership, or the 'rapid response team' on a television medical drama. *Do you agree that these are valid examples of "teams?" Did you come up with better ones?*

As with the term "quality," a universal *definition* of "team" would be difficult to devise. Here is one that we believe is useful:

A team is a *small number* of people with *complementary skills* who are committed to a common purpose, performance goals, and approach for which they hold themselves *mutually accountable*¹

On first reading, this sounds reasonable to most people. To better understand the implications, however, answer the following questions for yourself:

What is meant by "a small number"? Is two too few? Is nine (e.g., baseball) too many? Is there something important about how a team works that can't happen with a "large number" of people? Why should team members (e.g., a sports team) have complementary skills rather than identical skills? Does every member of a team really need to have common goals? Will significantly overlapping goals serve just as well? What is the difference between purpose and performance goals? If team members have complementary (i.e., different) skills, isn't that inconsistent with a "common approach?" How is "mutual accountability" handled? Shouldn't there be one "boss" to set the team's goals, to define the rules of interaction, to evaluate the performance, and to give rewards or punishments?

The material in this and following sections of the Workbook are designed to introduce students to a set of 'tools' that will facilitate a team's 'common approach developing the 'common approach'

Making Teams Out of Groups

We have introduced the idea of a team and begun with a definition of what a team is. Through the rest of this section we will discuss why and how teams are important in both the academic and work environments, learn what to expect during the formation and working life of a team, and learn strategies for maximizing a team's success.

1 1. Jon R. Katzenbach & Douglas K. Smith, *The Wisdom of Teams: Creating the High-performance Organization*. Cambridge, MA: Harvard Business School Press, 1993.

Introduction to Teams

What kinds of teams are there?

This lists some of the places teams are found and gives a rationale for *studying* how to become a team (It doesn't just 'happen'!).

In Industry / Business:

- Management teams (Team Xerox, San Diego Zoo)
- Continuous Quality Improvement teams (CQI)
- Design/Build teams (Chrysler H-car, Boeing 777)

In Academia:

- Cooperative learning
 - ä Short-term groups
 - ä Long-term groups
 - ä Base groups
- Project-based courses
 - ä Single-discipline teams
 - ä Multi-disciplinary teams
- Design Courses
 - ä Technical multi-disciplinary teams
 - ä Cross-functional teams (marketing, engineering, law, etc.)
- Other
 - ä A Department's Faculty

"The task for us at Boeing is to provide a massive change in thinking throughout the company - this is a cultural shift, and it isn't easy!"

**Phil Condit,
Executive Vice President
Boeing
Commercial Airplanes**

**You will be *hired* for your technical knowledge (or your ability to learn).
You will be *promoted* based on the quality of your communication skills.
You will be *fired* because of your lack of 'people skills.'**

-An 'old saw'

Recent numbers being quoted indicate that as many as 90% of the employee dismissals in large corporations are because the dismissed employee lacks interpersonal skills - they have a hard time working with fellow employees.

How Teams Handle Tasks (and why students are wary of working in teams)

Most of the problems facing society today consist of divisible, optimizing, conjunctive tasks that will be solved only by teams of people, working together. [If these terms are unfamiliar to you, you should look them up in a dictionary before proceeding.] While it is true that there are disjunctive efforts (one person discovers a concept and all may share the insight) and additive efforts (e.g., brainstorming) that are a part of these major problems, full solutions will require the expertise of a number of people, all of whom possess different pieces of the solution initially (i.e., they are primarily conjunctive efforts).

Introduction to Teams

Classification of Tasks :

1. Can the task be **SUBDIVIDED**?

Is it Divisible,
or Unitary (Indivisible)?

2. What is the **GOAL** of the task?

Is it to Optimize quality,
or Maximize quantity?

3. How are **INDIVIDUAL EFFORTS** related to the team's performance?

Is it Conjunctive: All team members must contribute to the task
 Disjunctive: If one gets it, then all get it (eureka/non-eureka)
 Additive: Rope tug, stuffing envelopes
 Compensatory: One person's extra effort makes up
 for another's reduced effort
 Discretionary: Team decides how individual efforts
 relate to team performance

If you have ever worked in a group before, try to recall if you have ever worked in any or all of the styles listed under #3. Most students have experienced 'compensatory' effort in group work. *If you have ever worked in a group exhibiting 'compensatory effort' was it your reduced effort that someone else made up for, or was it someone else's reduced effort that you made up for? How did this make you feel about working in this group?* The experience of having to make up for someone who doesn't 'pull their weight' in group work makes most students are hesitant about group activity - in fact they may strenuously object to being asked to work in groups again.

For successful team operation in academia, it is the responsibility of the instructors to structure the team's objective so that it requires the effort of everyone on the team. In cooperative learning, this is called building group interdependence.

Do Employers Want Team Skills in their Employees? How Do We Know?

What do you think industry expects of its new hires? Do you think that employers expect new hires to have team skills, or do you think they prefer to "train them up right" internally? Write a list of expectations you would have for new hires if you were managing a team effort in a local technology firm.



Introduction to Teams

The United States Department of Labor surveyed employers to find out what they were looking for in their employees². The study addressed their needs for all employees, not just for engineers or technologists. The list below summarizes the results. You should note that the study was completed in 1988 and the emphasis on interpersonal skills and self evaluation has definitely increased.

What employers want in their employees²:
<ul style="list-style-type: none"> • Learning to Learn • Listening and Oral Communication • Competence in Reading, Writing, and Computation • Adaptability: Creative Thinking and Problem Solving • Personal Management: Self-Esteem, Goal Setting/Motivation and Personal/Career Development • Group Effectiveness: Interpersonal Skills, Negotiation, and Teamwork • Organizational Effectiveness and Leadership

Which of the items in the list most agree with your expectations? Which item most surprised you? Do you think that answers given today would be very different from those given in 1988? How do you think they would differ?

For a more specific example, a Georgia-based company that employs engineers uses the form below during employment interviews:

POSITION _____		DATE: _____				
APPLICANT _____						
The Performance Skills to be evaluated	Evidence Skill NOT Present	Evidence Some Skill Present	Evidence Adequate Skill Present	Evidence Above Average Skill Present	Evidence Superior Skill Present	Insufficient Evidence for or Against Skill
(1) RISK-TAKING/INNOVATION						
(2) TEAM SKILLS						
(3) LEADERSHIP						
(4) PROBLEM-SOLVING SKILL						
NOTES:						

Finally, the table on the next page shows another example of what industry expects of its employees.

² *Workplace Basics: The Skills Employers Want*, American Society for Training and Development and U.S. Department of Labor, Employment and Training Administration, 1988.

Introduction to Teams

Rating	Description of performance at this level
100	Has demonstrated superior technical competence in a wide range of skills; <u>has displayed outstanding leadership and team skills at every opportunity</u> ; learns & adapts to changing circumstances quickly; achieves more than expected through consistently hard work & dedication;
90	finds innovative solutions to problems; demonstrates a passion for exceeding the expectations of customers; communicates exceptionally well spontaneously with little or no preparation.
80	
70	
60	
50	Has consistently applied acceptable technical competence within several skill areas; <u>has occasionally demonstrated strong leadership and team skills when conditions were favorable</u> ; adapts to changing circumstances and learns new skills when necessary; gets acceptable results and puts in "a good day's work for a good day's pay;"
40	occasionally develops innovative solutions to problems; shows a modest interest in meeting the needs of customers; communicates well with certain groups and on familiar topics.
30	
20	
10	Has marginal technical competence with certain skill areas; <u>displays little interest in assuming leadership; tends to cause dissension among team members; works best in isolation</u> ; resists change; shows pattern of absence from work suggestive of lack of
0	dependability; when faced with problems, seeks out others to solve them; demonstrates little concern for anticipating the needs of customers; awkward in communicating ideas to others

Overall
Rating
(1 to 100)

Factors to be
considered in making
overall rating:

Attitude
Ability to Learn
Results
Work Ethic
Technical Competence
Innovation
Leadership
Teamwork
Communication
Customer Orientation

*Actual rating form used by
an employer of engineers*

Introduction to Teams

What fraction of the overall rating made using these forms do you estimate would result directly or indirectly from team skills (or lack of team skills)? What fraction of the overall rating made using this form do you think would result directly or indirectly from technical skills (or lack of technical skills)?

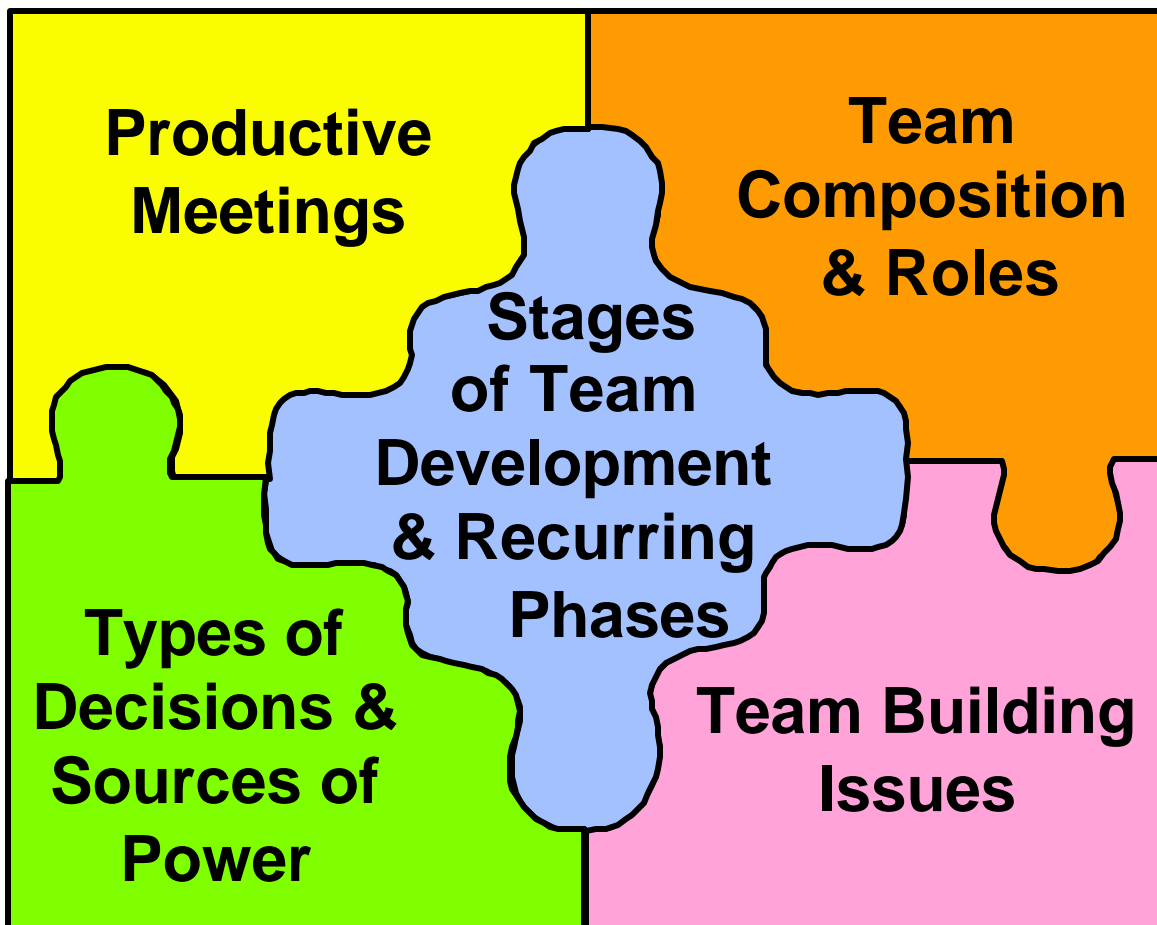
Does this help convince you that employers of engineers expect their employees to have team skills on joining the company, and to use those team skills while employed with them? If not, what kind of evidence would you need to be convinced of this?

Effective Teaming

How would you recognize an effective team? Take a few moments and write down as many attributes of a effective team that you can think of.



Effective teaming involves a number of interrelated issues. Some of the most important issues are presented in the illustration below, demonstrating their interdependence. ALL of these are necessary for effective teaming; really superb achievement in only area will not make up for poor achievement in another. This 'jigsaw' diagram will be used to help motivate an important 'jigsaw' exercise on teams during the semester.



Introduction to Teams

Stages in team Development³.

Can any group of people become a team? Can any group of *willing* people become a team? A good amount of research shows that teams don't just spontaneously form, and that expecting people to become a team without training can lead to disaster! Most students who have had negative past experiences with "teamwork" have really experienced somewhat poorly-organized "groupwork". The figure on the next page illustrates some of the common stages that a *group* will undergo on its way to becoming a *team*. It also illustrates that there *can* and likely *will be downs* before there are significant *ups* in the progress from group to team. The process starts with a **Working Group** – a group of people who have a range of levels at which they ordinarily perform. They begin with little or no teams skills. Follow along on the diagram and consider what happens as the team's skills grow . . .

1. Working group: This is a group for which there is *no significant incremental performance need* or opportunity that would require it to become a team. The members interact primarily to share information, best practices, or perspectives and to make decisions to help each individual perform within his or her area of responsibility. Beyond that, there is no realistic or truly desired 'small group' common purpose, incremental performance goals, or joint work products that call for either a team approach or mutual accountability. Note the varying levels of individual performance represented on the diagram.

2. Pseudo-team: This is a group for which there could be a significant, incremental performance need or opportunity, but *it has not focused on collective performance and is not really trying to achieve it*. It has no interest in shaping a common purpose or set of performance goals, even though it may call itself a team. Pseudo-teams are the weakest of all groups in terms of performance impact. They almost always contribute **less** to company performance needs than working groups because *their interactions detract from each members' individual performance without delivering any joint benefit*. In pseudo-teams, the sum of the whole is less than the potential of the individual parts.

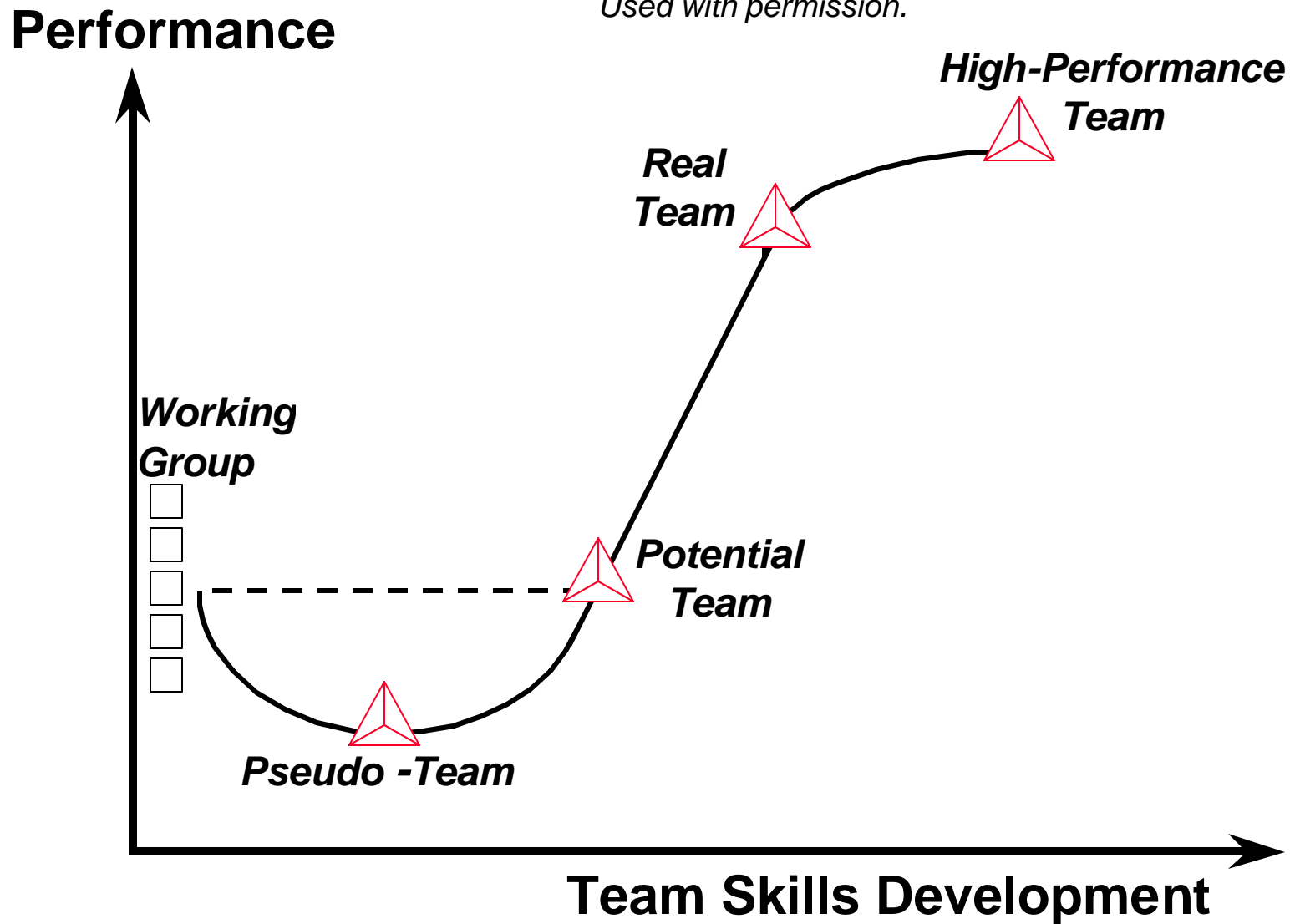
As Working Groups move toward becoming teams they **all** pass through this Pseudo-team stage and are less productive than when they were just a working group. The drop in productivity is caused by the team having to spend some (up to a significant amount of) effort at team building and not working directly on the project at hand. Learning how to make teams function takes time away from the task. If everyone in the Working group understands the issues of team dynamics (team building) the period of time spent as a Pseudo-team may be quite small but will not be zero.

³ The figure on the following page is from Jon R. Katzenbach & Douglas K. Smith, *The Wisdom of Teams: Creating the High-performance Organization*. Cambridge, MA: Harvard Business School Press, 1993. Reprinted by permission of Harvard Business School Press.

Introduction to Teams

From: Katzenbach & Smith, *The Wisdom of Teams:
Creating the High-Performance Organization*.

Used with permission.



Introduction to Teams

3. **Potential team:** This is a group for which there is a significant, incremental performance need, and *that really is trying to improve its performance impact*. Typically, however, it requires more clarity about purpose, goals, or work-products and more discipline in hammering out a common working approach. It has not yet established collective accountability. Potential teams abound in organizations. As our performance curve illustrates, when a team approach makes sense, the performance impact can be high. We believe the steepest performance gain comes between a potential team and a real team; but any movement up the slope is worth pursuing. Note that this increase in performance **requires** an increase in team skills!
4. **Real team:** This is a small number of people with complementary skills who are *equally committed to a common purpose, goals, and working approach for which they hold themselves mutually accountable...*
5. **High-performance team:** This is a group that meets all the conditions of real teams, and has *members who are also deeply committed to one another's personal growth and success*. That commitment usually transcends the team. The high-performance team significantly out performs all other like teams, and out performs all reasonable expectations given its membership. It is a powerful possibility and an excellent model for all real and potential teams.

Other authors have looked at the team formation process and described it in slightly different terms. For example, one source⁴ gives this table:

TABLE CHARTING THE FIVE STAGES OF GROUP DEVELOPMENT

STAGE	MAJOR PROCESSES	CHARACTERISTICS
1. Orientation (forming)	Exchange of Information; task exploration; identification of commonalities	Tentative interactions; polite discourse; concern over ambiguity; self-discourse
2. Conflict (storming)	Disagreement over procedures; expression of dissatisfaction; emotional responding; resistance	Criticism of ideas; poor attendance; hostility; polarization and coalition forming
3. Cohesion (norming)	Growth of cohesiveness and unity; establishment of roles, standards, and relationships	Agreement on procedures; reduction in role ambiguity; increased "we feeling"
4. Performance (performing)	Goal achievement; high task orientation; emphasis on performance and production	Decision making; problem solving; mutual cooperation
5. Dissolution (adjourning)	Termination of roles; completion of tasks; reduction of dependency	Disintegration and withdrawal; increased independence, emotionality, and regret

Do you see any commonality with the figure on the previous page?

⁴ Extracted from *Group Dynamics*, by Donelson Forsyth, adapted by Darwyn Linder, Dept. of Psychology, Arizona State University

Introduction to Teams

This section was intended to stimulate students to think about teams – what they are and are **not**, their importance to the modern work environment, and a bit about how they form. The two following sections will describe:

- team dynamics - how teams actually operate (as well as some suggestions for handling common team difficulties)
- communication – a very large topic that we will review briefly in order to help teams become aware of their approach to communication, and to help teams approach some common communication difficulties.

A final word about teams: it takes time, effort and energy to make them work well. They almost never work perfectly, but anyone who has been a member of a true, 'performing' team can tell you – the rewards are more than worth the trouble!

Introduction to Teams

And now, it's survival of the nicest New biologists tout unselfishness

By Robert S. Boyd
Knight-Ridder Newspapers
(Arizona Republic, Wednesday June 5, 1996)

WASHINGTON—Scientists are beginning to question the idea that nice guys are doomed to finish last.

For many years, biologists and anthropologists have regarded human beings as basically selfish creatures, driven by their genes to compete aggressively for property, sex and power.

In the 19th century, Charles Darwin described life as a tooth-and-claw struggle for "the survival of the fittest." Later, business tycoon John D. Rockefeller said his success was "merely the working-out of a law of nature and a law of God."

Even now, anthropologist Colin Trumbull dismisses morality as "a luxury that we find convenient and agreeable and that has become conventional when we can afford it."

It's a theory popular with macho politicians, businessmen, generals and stock-car racers.

But recent studies of chimpanzees and other higher animals show that unselfish, cooperative behavior goes way back in evolutionary history. Mother Nature apparently taught "family values" long before men and apes went their separate ways 6 million years ago.

This school of researchers contends that sharing, caring and peacemaking can contribute to the survival of a species, because creatures that get along with each other are more likely to reproduce and pass their genes on to future generations.

"There is always tension between taking care of oneself and taking care of others," said Sue Carter, a biologist at the University of Maryland. "But every mammal has to engage in some degree of positive social behavior. Previously, that has pretty much been ignored by science in favor of the study of aggression and antisocial behavior."

Frans de Waal, a zoologist who has studied chimpanzee behavior at the Yerkes primate Research Center in Atlanta for 20 years, disputes the traditional notion that people and other animals are hopelessly self-centered.

Instead, humans and higher mammals are biologically "endowed with a capacity for genuine love, sympathy and care," he writes in his new book, *Good Natured: The Origins of Right and Wrong in Humans and Other Animals*, published by Harvard University Press.

For example, de Waal says, whales and dolphins come to the rescue of injured companions. Elephants mourn their dead. Horses form a protective ring against attacking wolves. Beavers work cooperatively to dam a stream.

Chimpanzees, mankind's closest animal kin, show remarkable empathy - the ability to put oneself in another's shoes. Chimps share food, comfort the injured, protect the weak, celebrate births, grieve at deaths.

Introduction to Teams

"Aiding others at a cost or risk to oneself is widespread in the animal world," de Waal said. "No doubt these capacities evolved because they served a purpose in the lives of our ancestors."

This new breed of biologists asserts that unselfishness has "survival value." Creatures that assist each other in their struggle for existence usually do better in finding food or warding off enemies than those that only look out for themselves. Consequently, they are more likely to reproduce successfully.

"Social individuals leave more progeny than do solitary individuals," de Waal said. Carter, de Waal and like-minded biologists trace the origin of unselfish conduct to the maternal instinct that developed in mammals since they appeared on Earth 65 million years.

SECTION G

Team Dynamics Jigsaw

The slides in this section are used in an active learning jigsaw exercise on Team Dynamics. Members of a high performance team must share a certain set of skills, knowledge, and attitudes; this exercise is intended to introduce and practice this important set of skills, knowledge, and attitudes. The ideas and concepts introduced in this session of ECE 100 are used continuously throughout the semester; students will need to review these topics later in the semester as they are needed.

The material in this section is almost entirely reading material; it is organized into five topic areas. Students are normally assigned to read **all five** topic areas; however, they are only assigned **one** of these areas to study, understand, and present. The reading may be pre-assigned or may be done in class.

More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.

Team Dynamics

No matter how much native talent someone has for a particular activity (swimming, chess, singing, etc.), full development of that talent requires *study of the fundamentals* of the activity as well as *practice* of the activity. No matter how good the “people skills” of the members of a new team, the team’s performance will always be improved by practice of teaming skills, and by study of team dynamics.

Team Dynamics: What do we mean by this?

If you have never encountered the word “dynamics” before, take a few minutes and look it up. If you *have* encountered the word before, write down your best understanding of the word. How might this apply to *teams*?



Webster’s New World Dictionary gives the following definition of *dynamics*:

1. the science dealing with motions produced by given forces.
2. the forces operative in any field

It is easy to see how the interactions of team members are subject to many forces, both external and internal. For example, external forces might include pressure to complete a task by a deadline, or within a limited budget, while internal forces might include pressure by a team ‘faction’ to choose a certain course of action, or impatience of some team members with others’ modes of participation. (Can you think of any other “forces” that could influence the performance of a team?) Such “forces” can easily influence or change the “motion” of a team towards achievement of its tasks.

This purpose of the material in this chapter is to provide learning materials that describe some of what is known about how teams work. This field (or “science”, if you like) is very large, and we can only introduce you to some of what we believe are the more important topics. By studying the “science” of team dynamics, along with actual practice of team skills, you will greatly improve your team performance skills, and, we believe, the quality of the work your team produces. As in any activity (swimming, chess, singing, . . .), expect to make mistakes and some frustration, but also expect that you will improve in these very valuable skills.

Much of the material in this chapter will be labeled “Expert Table #n” because it is designed to be presented in a “jigsaw” fashion. We include a description of the jigsaw approach, however, the information is just as productively read as in a standard textbook. We hope that with this knowledge and with teaming practice you have positive, productive and rewarding experiences in teams throughout your career!

Team Dynamics

Team Dynamics Session Agenda and Goals

A typical agenda for the jigsaw exercise on team dynamics as given in ECE 100 is illustrated below. We usually show the video Meetings, Bloody Meetings as part of the team dynamics units, and so this is included in the agenda.

Team Dynamics Jigsaw Exercise	90 minutes
<i>Introduction</i>	<i>10 minutes</i>
<i>View the <u>Meetings, Bloody Meetings</u> video</i>	<i>30 minutes</i>
<i>Prepare a tutorial</i>	<i>20 minutes</i>
<i>Break</i>	<i>10 minutes</i>
<i>Reconvene in teams and deliver tutorials</i>	<i>20 minutes</i>
Creating & Maintaining your Team	10 minutes

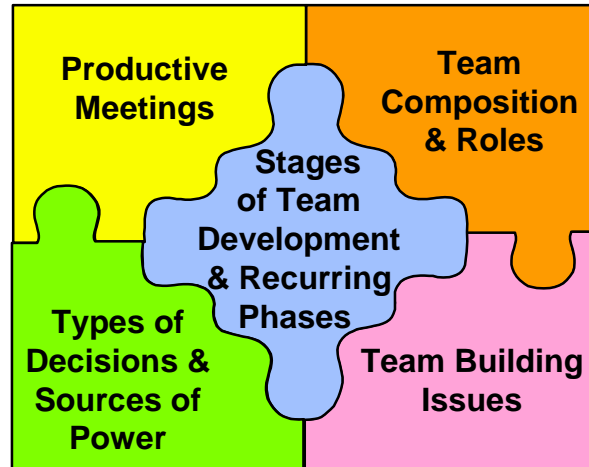
When the material in this chapter is presented as a jigsaw exercise, students must carefully read this material **before** class. The class period is used to **review** and increase student **understanding** of the material. Expecting students to come to class **prepared** is an example of the **Individual Accountability** facet of **Active Learning**, as described in Section B of this workbook.

The ECE 100 instructors have set specific learning goals for the material on Team Dynamics:

- Learn the essential elements of a functioning team.
- Learn some important aspects of Team building and Team functioning.
- Prepare and present a brief, informative presentation to a small group.
- Work as a group to accomplish a task.

(Defining the *goals* for the material is consistent with one of the attitudes we want students to adopt [*Begin With The End In Mind*, from Steven Covey's 7 Habits of Highly Effective People]; thus, we try to practice it in the classroom. Knowing what the instructor intends to accomplish in a class can be useful to students, particularly if they are trying to make confusing situations into something worthwhile. If instructors want students to develop this attitude, we need to demonstrate that the **instructors value** and *practice* this attitude (e.g., present session goals). There is another reason for presenting the goals; evaluation of the success or weakness of a session must include the goals *and* to what extent the goals were achieved.

Team Dynamics Jigsaw



Team Dynamics Jigsaw Exercise

Functioning as a successful team requires the integration of many different activities. If any piece of the puzzle is missing, then the groups of people is not likely to function as a true team. The figure above illustrates the main issues that will be covered in this material. It is laid out in the form of a jigsaw puzzle to illustrate the learning approach (Jigsaw exercise). A Jigsaw exercise is an active learning exercise in which:

- a general topic is divided into smaller, interrelated pieces (e.g., the puzzle is divided into pieces)
- each member of a team is assigned to read and become an *expert* on a different piece of the puzzle (e.g., one person is given the Team Building Issues puzzle piece, another the Team Composition & Roles piece, etc.)
- after each person has finished presenting their expert material to the rest of their team, the puzzle has been reassembled and *everyone* in the team knows something important about *every* piece of the puzzle.

The figure on the following page gives a process deployment flowchart that shows the structure of the suggested jigsaw process for this particular exercise. Some kind of *process check* at the end of the session is recommended, in order to make sure the exercise was successful and to identify ways to improve it. A suggested form for performing a process check is included at the end of this section.

Becoming an Expert

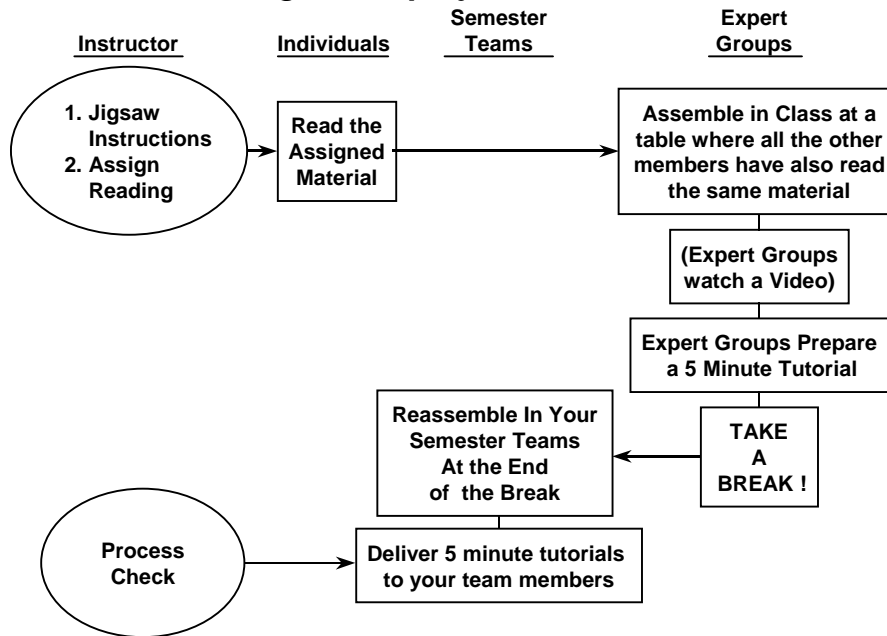
Expert groups are comprised of the representative from each team assigned to common reading. Expert groups discuss the reading material and help each other prepare a learning exercise (e.g., 5 minute tutorial) to use in educating their individual base or semester Team members later in the exercise.

Educating The Semester Team

One at a time, each team member presents the tutorial developed in their expert groups to the other members of their base or semester Team.

Team Dynamics

Jigsaw Deployment Flow Chart



Meetings Bloody Meetings

This video is one of the best resources we have seen for enabling students to learn about productive meetings. It is business-oriented (there appears to be no academic equivalent), but it is still very relevant to student teams. Although we have included material about productive meetings for use in the jigsaw exercise, we recommend that this video be shown if at all possible.

If this video is included as part of your team training, we suggest that as you watch the video, you:

- Assume that the people are a Team.
- Look for Examples of what you have read and studied about.
 - ✓ Composition and Roles in teams
 - ✓ Stages and Recurring Phases in teams
 - ✓ Effective Meetings

This video has many examples that can be used to help enhance the *expert tutorials*.

The expert material for each topic begins on the following page.

Five Issues to be Considered in Team Building

Team building exercises are very important in the development of task-oriented teams that will work together on a complex project for an extended period of time. Experiences designed to facilitate team development should be focused on some, if not all, of the following five issues:

1. Interdependence

Each team member's outcomes are determined, at least in part, by the actions of the other members. The **structure** of the team task should be such that it requires cooperative **interdependence**. Functioning independently of other team members, or competing with them, will lead to less than optimal outcomes for the entire team. The team building task should also have a cooperative interdependent structure. Tasks that require the successful performance of sub tasks by all team members are called **divisible** and **conjunctive** tasks. The team building exercise should be structured such that the team members become aware of, and experience, their interdependence.

2. Goal Specification

It is very important for team members to have common goals for team achievement; in addition, team members must communicate clearly about **individual** goals they may have. Some team building sessions consist entirely of goal clarification (**specification**) exercises. Shared goals is one of the definitional properties of the concept "team". A simple, but useful, team building exercise is to assign a newly formed team the task of producing a mission and goals statement.

3. Cohesiveness

Teams are **cohesive** to the extent that membership in them is positively valued; members are drawn toward the team. Task oriented teams involve both **social cohesiveness** and **task cohesiveness**.

Social cohesiveness refers to the bonds of interpersonal attraction that link team members. Although a high level of social cohesiveness may make team life more pleasant, it is not highly related to team performance. Nevertheless, the patterns of interpersonal attraction within a team are a very prominent concern. Team building exercises that have a component of fun or play are useful in encouraging attraction bonds to develop.

Task cohesiveness refers to the way in which skills and abilities of the team members mesh to allow effective performance. Exercises that require the application of the skills that will be necessary for completion of the team assignment, but require them in a less demanding situation, allow the team members to assess one another's talents. Such experiences can lead to consideration of the next issue, the development of team member's roles and of the norms that govern role enactment.

4. Roles and Norms

All teams develop a set of **roles** and **norms** over time. In task oriented teams, it is essential that the role structure enables the team to cope effectively with the requirements of the task. When the task is divisible and conjunctive (i.e., divisible into subtasks), as are most of the important team tasks, the assignment of roles to members who can perform them effectively is essential. Active consideration of the role structure can be an important part of a team building exercise. Task roles may be rotated so that all team members experience, and learn from, all roles. It is important that the norms governing the assignment of roles is understood and accepted by team members.

Norms are the rules governing the behavior of team members, and include the rewards for behaving in accordance with these rules (or **normative** requirements), as well as the sanctions for norm violations. Norms will develop in a team, whether or not they are actively discussed. There are common norms that govern most teams; however, a team building assignment in which those common norms, as well as some that are specific to a team, are discussed and accepted is useful.

5. Communication

Effective interpersonal **communication** is vital to the smooth functioning of any task team. There are many ways of facilitating the learning of effective communication skills. Active listening exercises, practice in giving and receiving feedback, practice in checking for comprehension of verbal messages, are all aimed at developing **communication** skills. It is also important for a team to develop an effective communication network; who communicates to whom; is there anybody "out of the loop?" Norms will develop governing communication. Do those norms encourage everyone to participate, or do they allow one or two dominant members to claim all the "air time?" Team building exercises can focus on skill development, network design, and norms, but even when the exercise is focused on another issue, communication is happening. Watch it! Shape it!

Summary:

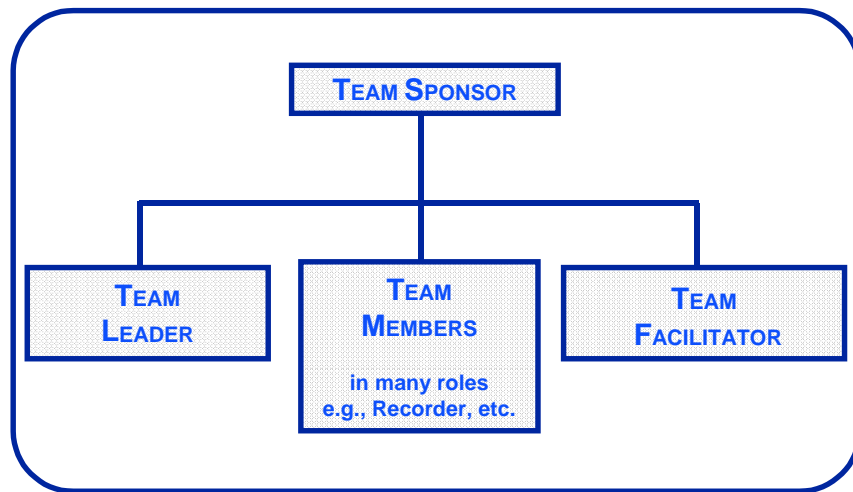
These issues are not intended to present a series of team building exercises. Rather, they are intended to help you evaluate the *potential* effectiveness of an exercise. Team building is not a silver bullet for fixing dysfunctional teams, or assuring that all of your teams will work well. Team building exercises can be helpful in developing effective task-oriented teams, if they are selected to enable teams to explore the issues identified in this outline.

Team Composition and Roles

It is essential that the right people be assigned to a team. Each person should be selected based on his or her knowledge and expertise as well as other potential factors. For example, in ECE 100 gender and ethnic diversity and geographic location are also important considerations when assigning team members.

In addition to selecting the appropriate *people*, there are also key *roles* that are essential to the overall team's success. Key roles include: sponsor, leader, facilitator, member, gatekeeper, recorder, timekeeper, and devil's advocate.

Team Organizational Structure



The figure above illustrates some important aspects of team organizational structure. Note that the Team Leader and Team Facilitator are 'on the same level' as all other Team Members (i.e., a 'flat' organization as opposed to the more common 'hierarchical' organizations)

Sponsor

The sponsor oversees and supports the activities of the project teams. Typically, the sponsor is the manager (or instructor) who chose the projects and appointed the teams; however, other people may be involved. Sponsors must have a stake in the chosen process; authority to make changes in the process under study; and clout and courage.

Sponsors do not conduct the actual project; they guide the efforts of the project team. They appoint the project team and together with the team leader determine the project's boundaries. They make certain the project team has whatever reasonable resources it needs to be successful. Sponsors must *adjust* workloads to make time for the project; team members must not take on the project work *in addition* to their normal workload.

The duties of the sponsor occur in two phases:

1. Before the project the sponsor should:
 - ✓ Identify the project to be studied.
 - ✓ Determine any boundaries or constraints.
 - ✓ Select the project team.
 - ✓ Assign the facilitator (if appropriate).
2. During the project, the sponsor should:
 - ✓ Meet regularly with the project team leader.
 - ✓ Develop and improve systems that allow team members to bring about change.
 - ✓ When necessary in the workplace, "run interference" for the project team, representing its interests to the rest of the organization.
 - ✓ Insures that changes made by the team are evaluated; implements changes the project team is not authorized to make (in the workplace).

The responsibilities of the sponsor are not finished until these changes are introduced, the improvements accomplished, or the new methods systematized and the project officially completed.

Team Leader

The team leader manages the team: calling and, if necessary, facilitating meetings, handling or assigning administrative details, organizing all team activities, and overseeing preparations for reports and presentations. The team leader should be interested in solving the problems that prompted the project, and be reasonably skilled at working with individuals and groups. Ultimately it is the leader's responsibility to create and maintain channels that enable team members to do their work.

Team leaders can be appointed by the sponsor or selected by the team itself. If the team leader is a supervisor or manager in the project area of the workplace, he or she must take extra precautions to avoid dominating the group during meetings. The leader leaves rank outside the meeting room, facilitating discussions and actively participating but as an equal member of the team.

The team leader:

- ✓ Is the contact point for communication between the team and the rest of the organization, including the sponsor.
- ✓ Is the official keeper of the team records including: copies of correspondence; records of meetings and presentations; meeting minutes and agendas; and charts, graphs, and other data related to the project.
- ✓ Is a full-fledged team member. As such, the team leader's duties also include attending meetings, carrying out assignments between meetings, and generally sharing in the team's work.
- ✓ Assists the team with immediately implementing changes that are within the bounds of the team. Changes beyond these bounds must be referred to the sponsor or other appropriate level of management.

Characteristics of a Good Team Leader

- ✓ Is energetic
- ✓ Is skilled at resolving conflict
- ✓ Is well organized
- ✓ Has experience as a group leader
- ✓ Is respected by group members
- ✓ Is reliable
- ✓ Is charismatic
- ✓ Is intelligent
- ✓ Is creative
- ✓ Possesses a sense of humor
- ✓ Is effective in achieving results

Facilitator

The ideal facilitator has a combination of people, technical, and training skills. In the workplace, facilitators should be chosen from outside the process area being studied so that they are neutral to the project.

Facilitators attend team meetings but are neither leaders nor team members. They are "outsiders" to the team, and maintain a neutral position. One of their most important jobs arising from this neutrality is to observe the team's progress, evaluate how the team functions, and use these observations to help the team improve its process (how members interact both inside and outside of meetings). The facilitator:

- ✓ Focuses on the team's process more than its product; is concerned more with how decisions are made rather than what decisions are reached.
- ✓ Works with the team leader between meetings to plan for upcoming meetings.
- ✓ Continually develops personal skills in facilitating, group processes, and planning. Learns a variety of techniques to control digressive, difficult, or dominating participants, to encourage reluctant participants, and to resolve conflict among participants. Learns when and how to employ these interventions and how to teach such skills to team members.
- ✓ Helps project teams design and rehearse management presentations.

The facilitator plays an important role in a team. It is this person's responsibilities to ensure that the process runs smoothly. In many companies this role is assigned to a person who may not be familiar with or have a stake in the outcome (the product) of the process. Then the facilitator is only interested in the process.

Some organizations do not provide an unbiased facilitator for each team, in which case a regular team member must act as facilitator. However, it is sometimes difficult to both monitor the process and participate in it.

In classes (e.g., design courses) this role is often assumed by the instructor, at least for the "meetings" that take place in her/his presence.

Katzenbach and Smith (*The Wisdom of Teams*) state that although a true facilitator is often needed to get a team started or to get a "stuck" team moving again, most often a team member can offer effective facilitation.

Team Member

Team members are the rest of the people involved in the project. Not everyone who could contribute something worthwhile need be on the team; project team members can always consult with experts or other staff as the project unfolds.

Team members are appointed by the sponsor. In the workplace team members are usually people who work closely with some aspect of the process under study; often representing different stages of the process and groups likely to be affected by the project. They can be of various ranks, professions, trades, classifications, shifts or work areas (if the project cuts across division boundaries, so should team membership). In ECE 100 team members are selected based on computing skills and geographic location. Gender and ethnicity are also considered in order to create diversity in class teams.

Team members

- ✓ Should remember that management has indicated their support for the project by setting up the project team. Therefore, team members should consider their participation as a priority responsibility, not an intrusion on their real jobs. Similarly, in ECE 100 team participation is a priority responsibility and should NOT be considered an intrusion on other class/course responsibilities.
- ✓ Are responsible for contributing as fully to the project as possible, sharing their knowledge and expertise, participating in all meetings and discussions, even on topics outside their areas.
- ✓ Carry out their assignments between meetings: interviewing other employees or customers, observing processes, gathering data, writing reports, and so on. These tasks will be selected and planned at the meetings.
- ✓ Should be open minded about others' ideas, share information, and contribute constructively to the team process.

Team members have more responsibilities than just showing up!

Characteristics of a Good Team Member

- ✓ Works for consensus on decisions
- ✓ Shares openly and authentically with others regarding personal feelings, opinions, thoughts, and perceptions about problems and conditions
- ✓ Involves others in the decision-making process
- ✓ Trusts, supports, and has genuine concern for other team members.
- ✓ "Owns" problems rather than blaming them on others
- ✓ When listening, attempts to hear and interpret communication from other's points of view
- ✓ Influences others by involving them in the issue(s)
- ✓ Encourages the development of other team members
- ✓ Respects and is tolerant of individual differences
- ✓ Acknowledges and works through conflict openly
- ✓ Considers and uses new ideas and suggestions from others
- ✓ Encourages feedback on own behavior
- ✓ Understands and is committed to team objectives.
- ✓ Does not engage in win/lose activities with other team members
- ✓ Has skills in understanding what's going on in the group

Miscellaneous Roles

There are a number of common cooperative learning roles that work well for teams in almost any situation. The roles should rotate with time. Assign as many as needed to cover all the members of the team. These are listed here in the order of decreasing importance to the team.

Recorder: The recorder is the team member who is responsible for assuring that the process(es) being used by the group is documented. This includes writing down all the important points of a discussion and preparing the minutes of a meeting. The recorder is also responsible for preparing slides and reports which the team needs.

Time Keeper: The time keeper has the responsibility of keeping the team moving so that the team finishes the task at hand.

Encourager: The encourager has the task of giving encouragement to all the other team members. When a team member makes a contribution, the encourager can comment "good idea" or "nice thought", etc.

Devil's Advocate: The devil's advocate takes a position opposite to that held by the team to ensure that all sides of an issue are considered.

Gatekeeper: The gatekeeper (a role sometimes taken by the facilitator or team leader) has the responsibility of maintaining a balanced level of participation for all the members. The gatekeeper will encourage the silent members and try to hold back the verbose, dominant members. A team functions when all members ideas and thoughts are heard; the gatekeeper helps ensure this.

Stages of Team Development (adapted from Forsyth, 1990)

Teams, like individuals, pass through predictable, sequential stages over time. Tuckman (1965) labeled the stages of team development as forming, storming, norming, performing, and adjourning.

Forming (the orientation stage)

Members of newly formed teams often feel anxious and uncomfortable. They must interact with other individuals whom they do not know well and begin to work on tasks which they may not yet completely understand. Their roles in the team and the procedures for interaction may be unclear as well. As members become better acquainted, some of the tension may dissipate. Members will begin to become more comfortable with their roles.

Storming (the conflict stage)

The polite interactions of the orientation stage may soon be replaced by conflict. False conflicts occur when members misunderstand or misinterpret each others behaviors. Contingent conflicts develop over procedural or situational factors (such as meeting times, places, or formats). These two types of conflict are relatively easy to resolve, whereas escalating conflicts, a third variety, may cause more serious problems for the team. Escalating conflicts may begin as simple disagreements which then lead into the expression of more fundamental differences of opinion. Such conflicts may be characterized by venting personal hostilities and the expression of long suppressed emotions or ideas. Although conflict may damage or destroy a team, most researchers agree that conflict is a natural consequence of team membership, and that it may, in fact, strengthen the team as the members learn to accept and constructively resolve their differences.

Norming (the cohesion stage)

During the third stage, team conflict is replaced by a feeling of cohesiveness. Teams experience a sense of unity or team identity. Membership stability also characterizes this stage. Members are highly involved and turnover is low. An increase in member satisfaction also happens at this time. Not only are members pleased with the team, but they themselves may experience higher self esteem and lower anxiety as a result of their participation in the team. The internal dynamics of cohesive teams change as well. Individual members are more likely to accept or be persuaded by team norms. One negative aspect of this is that, in some teams, dissent may not be tolerated during this stage.

Performing (the task-performance stage)

High productivity is most likely when teams have been together for some time. Whether the focus of the team is task oriented or therapeutic, effective performance occurs late in the developmental life of the team. Although, as a rule, non-cohesive teams are less productive than cohesive teams, not all cohesive teams are productive. Some cohesive teams may have strong norms which encourage low productivity.

Adjourning (the dissolution stage)

Teams may adjourn spontaneously or by design. Planned dissolution occurs when the team has completed its task or exhausted its resources. Spontaneous dissolution occurs when members are unable to resolve conflicts, its members grow dissatisfied and depart, or when repeated failure makes the team unable to continue. Either type of dissolution may be stressful. Members of successful teams may not want to end, and when the dissolution is unexpected, members may experience a great deal of conflict or anxiety.

TABLE CHARTING THE FIVE STAGES OF GROUP DEVELOPMENT

STAGE	MAJOR PROCESSES	CHARACTERISTICS
1. Orientation (forming)	Exchange of Information; task exploration; identification of commonalities	Tentative interactions; polite discourse; concern over ambiguity; self-discourse
2. Conflict (storming)	Disagreement over procedures; expression of dissatisfaction; emotional responding; resistance	Criticism of ideas; poor attendance; hostility; polarization and coalition forming
3. Cohesion (norming)	Growth of cohesiveness and unity; establishment of roles, standards, and relationships	Agreement on procedures; reduction in role ambiguity; increased "we feeling"
4. Performance (performing)	Goal achievement; high task orientation; emphasis on performance and production	Decision making; problem solving; mutual cooperation
5. Dissolution (adjourning)	Termination of roles; completion of tasks; reduction of dependency	Disintegration and withdrawal; increased independence, emotionality, and regret

Recurring Phases in Task Performing Teams

As teams perform, even those that have reached the performing stage in Tuckman's (1965) model of team development, they must focus on both the task and team maintenance in order to be highly productive. When a team directs attention at its primary task, it is almost inevitable that fatigue, tension, and conflict will develop.

Fatigue will set in if the task is demanding, or boredom will develop if it is too easy. Tension and conflict will develop when alternative approaches to task performance are suggested, or when alternative solutions to a team problem are put forward and discussed. As these products of a task orientation develop and increase, team productivity suffers. It is then important for the team to shift to a team maintenance orientation. This is accomplished by setting the task aside and focusing on the

relationships between members, resting, reducing tension, and resolving interpersonal conflicts.

In many teams there is a "rush to performance" in which the stages of team development are side-stepped or truncated. It is important to note that these stages of team development provide team members with the skills required during team maintenance activities. It is also important that members acknowledge the need to take time away from the task to deal with team maintenance issues. Two separate leadership roles may develop within a team, one person who directs task activities, and another who is the team maintenance specialist.

Team Maintenance

At various points in a team's history, there may be a need for team maintenance requiring various levels of intervention. There are three levels of intervention:

- ✓ Prevention
 - set the teams up for success
- ✓ Mild Intervention
 - impersonal, group time
 - private, non-meeting time conversation
- ✓ Strong Intervention
 - private, non-meeting time confrontation
 - personal, group time

Some functions necessary for task performance are:
<ul style="list-style-type: none">• Analyzing the problem or task structure• Suggesting solutions• Asking for information• Summarizing• Delegating• Refocusing team on task• Pushing for a team decision

Some functions necessary for team maintenance are:
<ul style="list-style-type: none">• Telling a joke• Mediating a conflict between team members• Encouraging all to participate• Showing approval• Suggesting a break from work• Reminding members of norms for cooperation• Encouraging and modeling positive affect for team members

Those Unwelcome Group Members¹

Many faculty who hesitate to use groups are reluctant because not all groups work well or efficiently. Even faculty who are committed to group work regularly search for ways to make students aware of processes that affect group productivity. Linda D. Lerner describes her strategy for making students aware of counterproductive behaviors in group situations. She has written short profiles designed to elicit very immediate and clear reaction from students.

¹ D. Lerner, "Making Student Groups Work," Journal of Management Education 19:1 (February 1995), pp. 123-125.

Lerner has her students discuss these profiles in small groups. She asks them to consider questions like the following: "Do you see yourself in any of these descriptions? What about other group members with whom you have worked? What problems do they present to the group? And, what are some strategies for dealing with these problems?"

Suggestions that groups offer for dealing with these behaviors can get compiled into a handout shared with all groups subsequently. This is an especially good *preventive* strategy.

Nola No-Can-Meet. Here's the group member who can't make the meeting, no matter when the others schedule it. She's willing to contribute, but she has a busy schedule and lots to do. The group should carry on without her, and she will do her part, as long as somebody lets her know.

Do-It-All Dottie. Dottie doesn't much trust other people and their ability to do things the way she thinks they ought to be done or up to her standards, so she does it all herself. If somebody offers to help, she puts them at ease: it's no problem, everything is under control, and they shouldn't worry. The less others in the group are involved, the happier Dottie is.

Seldom-Seen Steve. Nobody has seen hide nor hair of Steve. He isn't coming to class, he hasn't tried to contact anybody else in the group, and nobody knows how to get in touch with him. The project is just about due; what should the other members do about Steve?

Always-Right Artie. Artie definitely contributes to the group. His ideas are good and he's always ready to offer them. The problem: he doesn't listen very well to the ideas of others and he tends to force his solutions on the group. He takes charge and pushes the others in the direction that he thinks best, even though some in the group may not agree.

Quiet Quentin. Quentin is so quiet that the others often forget he's there, although he comes to the meetings quite well prepared. His ideas would really help the group, but unless they call on him, Quentin is unlikely to speak up.

Ten Common Team Problems	
1.	Floundering
2.	Overbearing participants
3.	Dominating participants
4.	Reluctant participants
5.	Unquestioned acceptance of opinions as facts
6.	Rush to accomplishment
7.	Attribution
8.	Discounts and "plops"
9.	Wanderlust: digression and tangents
10.	Feuding members

Six Types of Team Decisions

As a team works at a task, or at team maintenance functions, decisions must be made. The quality of team decision making, and the extent to which a decision is accepted and implemented by team members, is greatly affected by the decision making process. The six most common team decision making patterns are :

Unilateral/Authoritarian

One person makes the decision and imposes it upon the team. Often, there is very little input from team members, and acceptance/commitment is low.

Handclasp

Two team members make a decision and impose it upon the team. This pattern sometimes looks participatory, but it still involves little input from the other members, who will have a low level of commitment to the decision.

Minority

Several members make a decision and impose it upon the majority, who have been disenfranchised. In the hands of skilled practitioners, this may appear to be participatory decision making, but it is only a handclasp among a few members. Decision quality suffers because of the lack of input from the majority, and commitment to the decision is low among those outside the minority.

Majority

This is the popular, "democratic" default option. When a team is unable to resolve a conflict, there is almost always a suggestion to "take a vote, majority wins." Majority rule has the illusion of fairness, but it cuts off discussion, thereby reducing decision quality. Furthermore there is no commitment to the decision from the losing minority. The "loyal opposition" is often a myth. Super-majorities of 2/3 or 3/4 do not solve the problems associated with voting.

Unanimity

Solves the problem of commitment, but is very cumbersome because now everyone has a veto. The U. N. Security Council is a classic example.

Consensus

Consensus can be defined as *an agreed upon decision by all team members that reflects full exploration of a decision issue and does not compromise any strong convictions or needs*. Consensus is difficult to achieve, but results in the best decision quality and the highest level of commitment to the team decision. A consensus decision often becomes new policy

The search for consensus decisions is an important facet of teams. Consensus decisions are NOT based on the 'lowest common denominator'. The alternatives are discussed and refined until a consensus is attained. That may mean that no one gets exactly what he or she wanted, but everyone is able to say, "I might take a different course of action if it were entirely up to me, but I commit my support to the plan on which we have all agreed." Achieving consensus involves compromise on the part of all

members, but it is each member's responsibility to present her/his position as effectively as possible. Only then does consensus lead to high quality decisions.

The EXPLICIT development and use of 'social norms' (See Section H – Team Norms and Communication) for a team is the essential ingredient that makes consensus decisions differ from the 'lowest common denominator'. 'Forced' or 'one time' compromises that are common to the political process are NOT desirable and do NOT represent consensus decisions. Every team member (and the team sponsor) should be willing for the outcome of the consensus decision process to represent the future policy of the organization.

There are degrees of commitment to consensus just as there are degrees of internalization for affective behavior.

Low Level Commitment (Passive Acceptance) You are willing to accept the decision but you do not feel very good about the decision. You work to implement the decision but your heart is not really in the implementation. You do not actively support the decision with your colleagues and team members (but you also do not work to sandbag the decision).

Moderate Level Commitment You feel good about the decision and work to implement it. Your general sense is much more positive than at the lower level but you may still not actively support the decision with colleague.

High Level of Commitment (Active Acceptance) You feel good about the decision, even when it is not the one you initially started out with. You know that the decision is the best for the team and you actively work to get it implemented and accepted by other colleagues and team members.

One other thought: CONSENSUS is not about voting. If you are voting then you are not talking about consensus; you are talking about UNANIMITY. Consensus is an attitude and feeling and is something reached or achieved, never voted on. It sometimes happens that a decision is reached that is apparently a consensus decision – all team members appear to agree (at least, none are objecting), the issue appears to have been fully explored (at least, no one is introducing any new information or concerns), and there seems to be no one seems to be compromising their convictions or needs (at least, no one is *complaining*). Unfortunately, when a team is fatigued, the focus of the team is wandering, or team maintenance is overdue, a state of Group-NO-Think sometimes occurs (see Section G – recurring Phases in Teams). A NO-Think decision can appear to be a consensus decision simply because team members are too fatigued to speak up regarding their concerns, or wish not to give offence, or believe that everyone else already agrees and they should just go along.

The following strategies can help overcome Group-NO-Think:

- ✓ De-emphasize status and power differences between members.
- ✓ Welcome outside viewpoints.
- ✓ Encourage disagreement or clash of opinions.
- ✓ Assign one member the task of being a devil's advocate.

There is a favorite sit-com plot device wherein a group of people winds up doing something that no one in the group really wants to do, because each group member thinks *everyone else* in the group wants to do it. This phenomenon is sometimes called the “Abilene Paradox” from the training movie “The Road to Abilene” in which a group of people does not wish to offend its leader, and so agrees to go to Abilene, 60 miles away, to get ice cream. When they arrived after some unpleasantness, it turned out no one wanted ice cream and everyone had just thought everyone else wanted to go.

Sources of Power in Teams

The ability of an individual to influence others within the context of a small, task-oriented team is determined by the power of that individual. There are five sources of social power; some are more effective than others.

Legitimate Power. This power results from the position the person holds. A designated or elected leader, a military commander, a manager, all have legitimate power, power that is inherent in the position. Generally, influence based on legitimate power will be accepted by team members; however, it is important that they accept the legitimacy of the power hierarchy.

Reward Power. This power is based on the ability of the person to control important sources of reward and reinforcement. Salary, bonuses, time off, access to resources, are all rewards that can be used to influence behavior. Reward power is usually well accepted by team members if the rewards are administered within clear contingencies and guidelines.

Coercive Power. This is the power to administer punishment for noncompliance. Fines, suspensions, undesirable assignments, verbal abuse, ridicule, are all examples of punishment or coercive power. The application of coercive power usually leads to compliance, but also generates resentment, negative emotionality, and dislike for the person who uses it.

Expert Power. This form of power is based on the knowledge, special skill, training, or experience of the person. When a person's expertise is known to the team, influence within that area of expertise is well accepted. The user of expert power must find a balance between being haughty and being too humble. Bragging about your skills does not establish useful expert power; however, expert power can not be used if no one knows about it.

Referent Power. This is power based on the person's attractiveness and qualities as a human being. It is called "Referent" because teams members use this person as a point of reference in developing their own personalities. Referent power depends upon developing positive relationships with team members. It is not simply mutual attraction, but a relationship that includes a kind of mentoring and guidance that is possible because one person wants to learn from the other.

The use of power in teams is an ongoing process. The sources of power that are most useful to leaders and facilitators are expert power and referent power. They produce influence and change in a positive way, and minimize resistance and negativity. Reward and legitimate power can also be used effectively and in a positive way. Coercive power can quickly produce the desired behavior, but leads to other, undesirable consequences.

Guidelines for Productive Meetings

Although individual team members perform assignments between team meetings, much of the team's work gets done when all team members are together during meetings. Many people dislike meetings; however, productive meetings enhance the chance of having a successful project. Just like other processes, meetings can be studied and constantly improved.

It is difficult to have productive meetings because few people know the rules and skills needed for such meetings. In fact, the goal of having constantly improved meetings may be as hard for the team to reach as the improvement goals set for the project. The best way to have productive meetings is to follow the guidelines given below from the start of the project when the members expect to learn new ways of working together.

1. Use agendas

Each meeting must have an agenda, preferably one drafted at the previous meeting and developed in detail by one or two members prior to the actual meeting. It should be sent to participants in advance, if possible. (If an agenda has not been developed before a meeting, spend the first five or ten minutes writing one on a flipchart.)

Agendas should include the following information:

- ✓ The agenda topics (including, perhaps, a sentence or two that defines each item and why it is being discussed), presented in a logical order so that items that need to be decided first are addressed first..
- ✓ The process to be used in coming to a decision (e.g., brainstorming, affinity process, multi-voting, etc.) and not simply state "discuss. . ."
- ✓ The presenters (usually the person who originated each item or the person most responsible or knowledgeable about it).
- ✓ A time guideline (the estimated time in minutes needed to discuss each item).
- ✓ The item types (does each item requires discussion or decision, or is just an announcement).

Agendas usually list the following activities:

- ✓ Warm-ups : short (five to ten minute) activities used to free people's minds from the outside world and get them focused on the meeting.
- ✓ A quick review of the agenda : start each meeting by going over the agenda, adding or deleting items, and modifying time estimates.
- ✓ Breaks for long meetings : if the meeting lasts more than two hours, schedule at least one short break.
- ✓ Meeting evaluation : this is perhaps the most important item on the agenda.

Although some of these elements may be unfamiliar, we encourage team leaders to introduce them at the first meeting and include them in all subsequent meetings. Team members will probably feel awkward at the first meeting anyway, and a new activity will not add much to that awkwardness. As members become more comfortable with the group, they will feel less self-conscious about these activities.

2. Have a facilitator

Each meeting should have a facilitator who is responsible for keeping the meeting focused and moving. Ordinarily, this role is appropriate for the team facilitator; however, your ECE 100 team may rotate the responsibility among its members.

Among the facilitator's chief responsibilities are:

- ✓ encourage compliance with the Code of Cooperation and other team norms;
- ✓ keep the discussion focused on the topic and moving along;
- ✓ intervene if the discussion fragments into multiple conversations;
- ✓ tactfully prevent anyone from dominating or being overlooked;
- ✓ bring discussions to a close.

The facilitator should also notify the group when the time allotted for an agenda item has expired or is about to expire. The team then decides whether to continue discussion at the expense of other agenda items or postpone further discussion until another meeting.

3. Take minutes

At each meeting one team member should record key subjects and main points raised, decisions made (including who has agreed to do what and by when), and items that the team has agreed to raise again later in this meeting or at a future meeting. Team members can refer to the minutes to reconstruct discussions, remind themselves of decisions made or actions that need to be taken, or to see what happened at a meeting they missed. **Rotate this duty among the team members.**

4. Draft next agenda

At the end of the meeting, draft an agenda for the next meeting.

5. Evaluate the meeting

Always review and evaluate each meeting, even if other agenda items go overtime. The evaluation should include decisions on what will be done to improve the meeting next time and helpful feedback to the team leader. You may want to experiment with mid-meeting evaluations.

6. Adhere to the "100-mile rule"

Once a meeting begins, everyone is expected to give it their full attention. No one should be called from the meeting unless it is so important that the disruption would occur even if the meeting was 100 miles away from the workplace. The "100-mile rule" will need to be communicated--perhaps repeatedly--to those who keep taking phone messages or would interrupt the team's work for other reasons.

Summary: The Structure of an Effective Meeting

Have a Detailed AGENDA

- ✓ Issued in advance of meeting
- ✓ Preassigned meeting roles
- ✓ Agenda topics
 1. A sentence or two defining the item including a clearly articulated objective
 2. In logical order of action
- ✓ Presenters, Resources Required, Assignments, etc.
- ✓ Time guideline

Use Quality Tools

- ✓ Appropriate tool for the task at hand
- ✓ Team trained in use of tool

Perform a Post-meeting evaluation (Process Check)

Comply with Team Norms

- ✓ Is everyone participating?
- ✓ Is no one dominating?
- ✓ Are team roles being followed?
- ✓ Is the team staying on task?
- ✓ Is the team reaching consensus?
- ✓ Are team members coming prepared to work?
- ✓ Are team members arriving on time?
- ✓ Do the team members understand the decision tools being used?

Continually Check the Team's Effectiveness

- ✓ Are we doing the right things?
- ✓ Are we asking the right questions?
- ✓ Are we tackling the right problems?

Continually Check the Team's Efficiency

- ✓ Are we taking unnecessary steps?
- ✓ Are we reinventing the wheel?
- ✓ Are we spinning our wheels?
- ✓ Are we looking for process related problems?
- ✓ Are we using appropriate quality tools?
- ✓ Are we straying from the agenda?

Process Check : Team Dynamics

As a team, briefly discuss each item. Try to come to a **team** decision on each item before circling the answer that best describes the team's assessment. In the bottom box, please make a suggestion for improving the session on Team dynamics. Suggestions should be realistic, under the control of the instructors, and intended to help future students better achieve the learning goals of the session.

	AGREE			DISAGREE	
	1	2	3	4	5
The team now knows the importance of teams					
<i>As a member of this team, I now know about:</i>					
Productive Meetings					
Team Composition and Roles					
Stages of Team Development					
Team Decisions					
Consensus and Group-NO-Think					
Recurring Phases in Team Functioning					
Sources of Power in Teams					
Issues in Team Building					
All team members participated					
The team stayed focused on task					

In this box, please list a change in today's class that would enable your team to learn more effectively:

SECTION H

Team Norms and Communication

The slides in this section are typically used to present the concepts and practice the skills needed to develop team social norms (i.e., accepted behaviors). The importance of verbal communication and its impact on team performance is emphasized in this material. Some useful discussion tools are introduced and practiced.

More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.

Team Norms and Communication

Communication? Isn't this an *Engineering* class?

Communication is something we have been doing all of our lives, so why do we spend significant effort in a *University-level engineering* course on communication? One reason is that employers of engineers, when asked what they look for in new employees, nearly unanimously list communication skills as a top priority (see section F – Introduction to Teams).

There are many reasons why engineers need good communication skills. Engineers need to communicate well with customers in order to understand and meet their needs (see section E – Quality). Engineers need to communicate with project sponsors to fully understand project inputs and constraints, and they need to clearly communicate their designs to the project sponsors. Engineers need to communicate with engineer and non-engineer team members in order to productively complete team tasks and to derive the maximum benefit from teamwork.

If it seems as if too much attention is being paid to communication at the expense of technical issues, consider the following:

Even the most innovative, valuable, and important technical work of the decade, inadequately communicated, will never be implemented, or even recognized.

On the other hand, flawed technical work that is well-communicated, even if it is flawed, can be improved, can be evaluated, and can ultimately be implemented.

Take a few minutes and try to recall some examples from you own knowledge or experience in which poor communication led to a problem not being solved, a problem's solution being delayed, or a poorer-quality solution than possible being implemented.



This Workbook section will discuss oral communication in high-performing teams (Written communication is addressed in Section J). In addition to the discussion on communication, this section is also concerned with **team norms**, the mutually-agreed upon standards of behavior of team members.

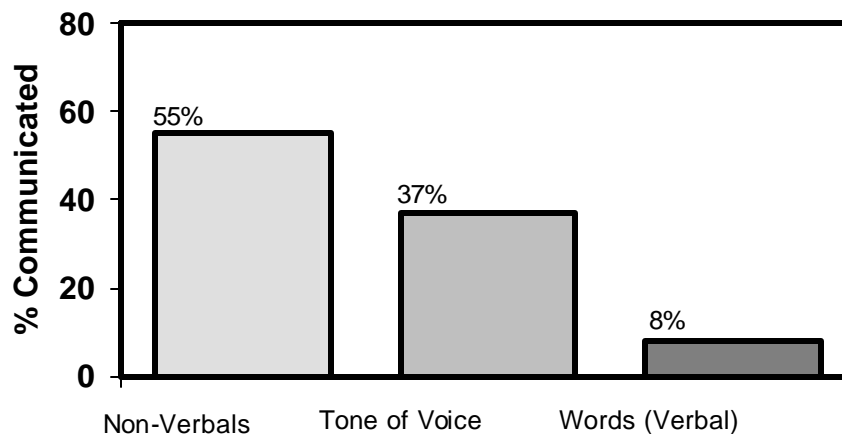
Team Norms and Communication

Many people have had the experience when sending electronic mail of inadvertently confusing, annoying, or offending the email recipient. Humor, it turns out, is *especially* difficult to communicate using printed words alone. This has led to the (spontaneous?) development of a set of symbols, called 'smileys' or 'emoticons', used in electronic mail and other electronic media to communicate emotional state along with the words being sent. (one listing of 'smileys' can be found at <http://www.netlingo.com/smiley.cfm>).

Common 'Smileys'			
: -)	Basic	: -*	Kiss
:)	Basic Little Kid	(-:	Left Hand
(:-)	Big Face	: -{	Mustache
: -]	Blockhead	: (Sad Little Kid
; -(Chin up	: -/	Skeptical
: -S	Confused	; ^)	Smirking
:`-(Crying	: -0	Surprised
> :->	Devilish	: -\	Undecided
:")	Embarrassed	'-)	Winking
> -)	Evil Grin	, -)	Winking Happy
: -!	Foot in Mouth	, -}	Wry and Winking

Long before electronic communication became widespread, social scientists had studied the roles of verbal and non-verbal elements of communication. The figure below illustrates a very important finding: in face-to face communication, the words used contribute less than 10% of a communication – non verbal visual and auditory signals communicate over 90% of the content!

Elements of Face-to-Face Communication



Team Norms and Communication

Communication is more than what we say or even what we mean to say. It is what our listeners think they heard and what they think we meant. Our intentions may not equal their perceptions. What they heard may not be what we meant. What eventually lodges in each person's mind has as much to do with our internal filters, the mood we are in, when the conversation took place as it does with words actually spoken.

These factors should be taken into account when clear communication is the goal. Communication is a total of all the things said -- and not said. Signals may be sent by the *absence* of communications as clearly as by any carefully worded announcement. Such signals are all most invariable the wrong ones. In the absence of direct information that is frequently disseminated, people will fill in the blanks themselves with preconceived notions, hearsay, personal opinions and innuendoes. Silence is often more harmful than simply providing people with the facts.

Communication Roadblocks

Communication doesn't always go well, even when those communication have the best of intentions. There are *behaviors* (as distinguished from *attitudes*) that have been found to be particularly destructive to good communication. Can you think of any?



After you have come up with your own list, look over the list of communication roadblocks given below. Try ranking them according to how much these behaviors bother you. Then try ranking your *own* behavior – which of these are *you* most likely to exhibit? Consider asking a friend or a family member to rank the behaviors according to how often *they* think you exhibit the behaviors.

Communication Roadblocks

❖ Directing		❖ Moralizing
❖ Interrupting		❖ Persuading
❖ Judging		❖ Ridiculing
❖ Name Calling		❖ Warning

Team Norms and Communication

Listening Skills and Techniques

Clarity is a key to effective communication. All communication involves both a *sender* and a *receiver*. As a result, not only does the sender need to master effective communication skills, but *the receiver must also master effective listening skills*. Good listening means that your mind is open to what the other person is trying to convey.

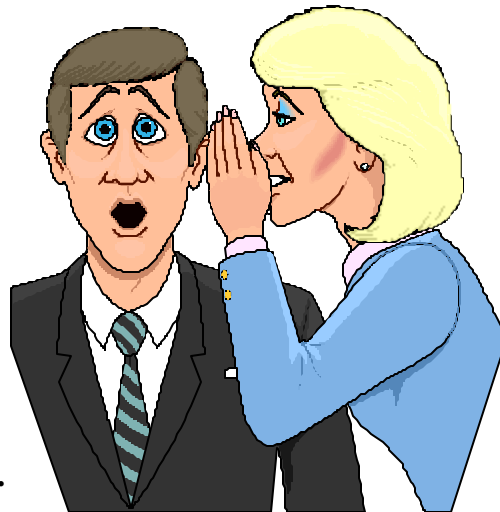
Below is a list of behaviors that characterize **good listening**. Try ranking them according to how important these behaviors are to you. Then try ranking your *own* behavior – which of these are *you* most (and *least*) likely to exhibit? Consider asking a friend or a family member to rank the behaviors according to how often *they* think you exhibit the behaviors.



It is important when listening to listen for what is *not said* as well as what is said. The authors believe that much of engineering involves trying to define the real problem (extract real problem from stated problem). This alone makes effective listening a critical skill for engineers.

Effective Listening Behaviors

- ❖ Stop talking.
- ❖ Engage in one conversation at a time.
- ❖ Empathize with the person speaking.
- ❖ Ask questions.
- ❖ Don't interrupt.
- ❖ Show interest.
- ❖ Concentrate on what is being said.
- ❖ Don't jump to conclusions.
- ❖ Control your anger.
- ❖ React to ideas, not to the person speaking.
- ❖ Listen for what is not said. Ask questions.
- ❖ Share the responsibility for communication.



We all value information differently, depending on its source, and tend to voice agreement with the opinions of those whom we respect. However, the question should never be *who* is right, but *what is* right.

Not only are there behaviors that characterize good listening, there are different techniques of listening, for when the *goals* of the listener might vary. Some of these 'Listening Techniques' are given below. Although you might find a use for each of them at one time or another in team communication, Creative Listening is what makes teams so powerful, because the synergism possible using creative listening is great.

Team Norms and Communication

Listening Techniques

In **Critical** Listening

Your Goal is to: Separate fact from opinion

So the Listening Behaviors that are most useful are:

1. _____
2. _____
3. _____
4. _____
5. _____

In **Sympathetic** Listening

Your Goal is to: _____

So the Listening Behaviors that are most useful are:

1. Don't talk, give advice, or judge - listen.
2. _____
3. _____
4. _____
5. _____

In **Creative** Listening

Your Goal is to: Supplement your ideas with another person's Ideas and vice versa.

So the Listening Behaviors that are most useful are:

1. _____
2. _____
3. _____
4. _____
5. _____

Communication Tools

Talking Chips¹

One of the most difficult aspects of group communication to monitor and regulate is that everyone have an equivalent opportunity to speak. Some people, for example, think and speak quickly, enabling them to 'jump in' to a conversation at the merest pause; others need time to reflect and have been raised to expect a significant pause when one speaker ends and before another begins. Also, when a conversation gets team members emotionally engaged, members can be less scrupulous in ensuring that everyone get a chance to speak.

For these and other reasons, it is useful to have "communication regulators" available to help ensure productive team communication. The one we will discuss here is called "Talking Chips".

¹ Spencer Kagan describes a number of 'communication regulators' including Talking Chips, Colored Chips, Response Mode Chips, and Paraphrase Passport in Chapter 13 of his book, Cooperative Learning (1992, San Juan Capistrano, CA: Resources for Teachers)

Team Norms and Communication

To use this technique, each person in the group selects a 'totem', for example, their pen or pencil. A person who wishes to speak places their 'totem' in the center of the table, or somewhere else clearly visible to all. That person speaks as succinctly as possible, but gets to have their full say, without interruption. The others listen quietly.

When that person signals that they are done, the next person who wishes to speak places *their* totem onto the table, and has their full say.

This continues until every person in the group has spoken. A member of the group who does not wish to speak must say so, and then place their token on the table.

The important rule is that no one may speak a second time until **all** totems are out. This prevents one or more group members from dominating the discussion; gives quieter or more slowly speaking members a full chance to have their say, and helps create an environment where anyone who is not speaking can listen carefully without needing to be ready to 'jump in' at their first chance.

Once all have had a chance to speak, then the totems are taken back, and another round of speaking can occur.

Paraphrase for Understanding (Seek First to Understand, Then to be Understood²)

Often when we speak in conversation, we spend the time that we are not actively speaking in *preparing our reply*, instead of carefully listening. One method of assuring that non-speakers are **actively listening**, is to listen with the intent of paraphrasing what the speaker is saying. This method, used often during professional mediation and conflict resolution, goes like this:

- The *speaker* explains their idea/position/opinion
- The *listener* paraphrases what they heard the speaker say
- If the speaker agrees that the listener has fairly represented what they said, then the listener has a turn to speak (and the first speaker then paraphrases)
- If the speaker does *not* agree, then the speaker attempts to clarify, and the listener again tries to paraphrase until the speaker agrees that the listener has fairly represented what they said.

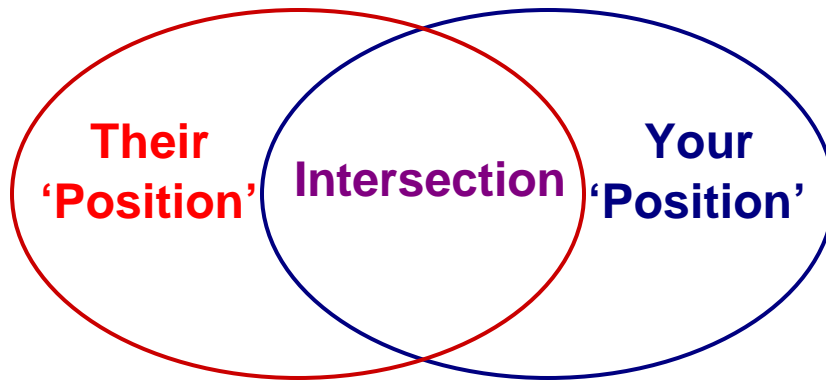
Listeners must not add anything or embellish the material, but must paraphrase as exactly as possible. It is especially important for listeners not to imply content that the speaker did not say. This approach is sometimes called 'empathic' or 'reflective' listening. The technique takes a bit of practice but can open up a conversation – both because the listener must listen carefully, and because the speaker hears back exactly what they said.

FIRST Seek the 'Intersection'

A recommended or example social norm for overcoming 'deadlock' or 'gridlock'. The basic concept is to begin by determining what are the core areas of agreement and then proceeding to move carefully outwards towards the areas of disagreement when seeking consensus.

² Covey, Stephen R., *The 7 Habits of Highly Effective People*, (1989), Simon & Schuster, Habits 4 and 5.

Team Norms and Communication



The technique is fairly straightforward:

- First, see the problem from the other point of view; really seek FIRST to understand!
- Second, identify the 'Intersection' (i.e., where the 'positions' clearly overlap).
- Finally, select ONE issue at a time from outside the 'Intersection' to discuss and resolve.
- Select the issues that are 'closest' to the 'Intersection' and work 'outwards' from there, alternating between 'their position' and 'your position'.

One of the authors (Bellamy) saw this technique work in oil negotiations in the Middle East. The negotiating parties went from confrontation to agreement in about 11 days by starting with what they agreed on.

This process is one you can try when the discussion is clearly going no where

Constructive Feedback

Constructive Feedback is communicating the effect that another person's or team's behavior has on you, and listening as that person or team communicates their reactions to, feelings about, and perceptions of *your* message.

Most of us would agree that at its best, communication must be honest and sincere; however, think about how often it is not. We are often tempted to take the easy way and say things we don't mean or to avoid telling someone what the problem really is or that his/her performance is lacking. Honest, direct communication often demands courage. Thus, constructive feedback is also a key component of effective communication.

Constructive Feedback is a very important tool but also one that is very hard to do. It is important that you only give constructive feedback to someone when you *care about* that person's feelings and how they think about you. If you do not care about the person then attempting this technique can exacerbate communication problems, rather than improving them. For this reason, at a very early stage of team training it makes little sense to practice this technique, and it can be considered as a technique to be used by people in fairly strongly-established relationships. Constructive feedback can be one component of a **process check**.

Team Norms and Communication

Constructive Feedback

You **ARE** an expert on:
how **other people's** behavior
affects you,
and on
your feelings.

You are **NOT** an expert on:
how **your** behavior
affects other people,
nor on
other people's feelings.

How to Give Constructive Feedback

1. "When you . . ."
Start with a "When you . . ." statement that describes the behavior without judgment, exaggeration, labeling, attribution, or motives. Just state the facts as specifically as possible.
2. "I feel . . ."
Tell how their behavior affects you. If you need more than a word or two to describe the feeling, it's probably just some variation of joy, sorrow, anger, or fear.
3. "Because I . . ."
Now say why you are affected that way. Describe the connection between the facts you observed and the feelings they provoke in you.
(Pause for Discussion)
4. Let the other person respond.
5. "I would like . . ."
Describe the change you want the other person to consider ...
6. "Because . . ."
... and why you think the change will alleviate the problem.
7. "What do you think . . ."
Listen to the other person's response. Be prepared to discuss options and reach consensus on a solution.

How to Give Constructive Feedback: An Example

1. "When you . . ."
"When you are late for team meetings,
2. "I feel . . ."
I get angry ...
3. "Because I . . ."
... because I think it is wasting the time of all the other team members and we are never able to get through all of the agenda items."
(Pause for Discussion)
4. Let the other person respond.

Team Norms and Communication

5. "I would like . . ."
"I would like you to consider finding some way of planning your schedule that allows you to get to these team meetings on time . . ."
6. "*Because* . . ."
. . . because that way we can be more productive at the team meetings and we can all keep to our tight schedules."
7. "*What do you think* . . .?"

Step 1 utilizes the fact that that you are an expert on other peoples *behavior*, and Step 2 utilizes the fact that you are an expert on *your feelings*

The last four steps of the process i.e., requesting a change in another person's behavior, is the most difficult part. The discussion cited in step 4 is an essential step in 'clarification' and 'check for understanding'. Once again, consensus decisions are required.

When starting this process, it is a good strategy to start with POSITIVE feedback first, that is, telling someone how something they do makes you feel good. This technique can be combined with 'Paraphrase for Understanding'

Team Norms

Social norms are the agreed upon behaviors, attitudes, values, etc. which hold 'society' in general, and teams in particular, together. In society at large these may be implicit or explicit; however, they **must** be commonly understood, reinforced, and taught. In the team environment, they also **must** be **explicit**, **reinforced** and **learned** by all **team** members.)

Sociologists believe that it is upon the 'norms' that a society is built. They see these 'norms' as the 'glue' which holds society (culture, subculture, team, etc.) together. When establishing a team, the **Code of Cooperation** is one way to *explicitly* develop norms and serves to create a basis for organization and social interaction. When agreed upon norms start to fall apart or people disregard them and there is nothing to take their place, cohesiveness ceases. The disintegration of norms creates disorganization, which may lead to a the team losing its sense of purpose. Then the team is really in trouble!

All of the issues and problems that can, and do, arise as a natural consequence of using teams need to be addressed by the team; preferably using a standard process. In this section, we will present a process for improving and maintaining team communication skills.

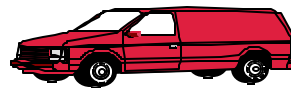
The process presented in this section includes the development of '*team norms*' that can be used to reduce, if not eliminate, the impact of these issues and problems on team performance. This is your opportunity to learn how to effectively (or affectively) address many concerns you may have about working in groups; e.g., 'He is always late or skips scheduled meetings,' 'She is never prepared.', 'He never completes his part of the problem or assignment', 'She always wants to copy my work and that's cheating', etc.

Team Norms and Communication

‘Ten’ Commandments* An Affective Code of Cooperation

*Ford Motor Company

1. Help each other be right, not wrong.
2. Look for ways to make new ideas work, not for reasons they won't.
3. If in doubt, check it out! Don't make negative assumptions about each other.
4. Help each other win, and take pride in each other's victories.
5. Speak positively about each other and about your organization at every opportunity.
6. Maintain a positive mental attitude no matter what the circumstances.
7. Act with initiative and courage, as if it all depends on you.
8. Do everything with enthusiasm; it's contagious.
9. Whatever you want; give it away.
10. Don't lose faith.
11. Have fun!



A Process for Generating Team Norms

The process traditionally used in ECE100 for generating a set of team Norms begins with an out-of class assignment in the Concepts or Laboratory session. Each student is required to come to class with an individually-prepared set of:

- Promoters of Effective Teams
- Barriers to Effective Teams

These are compiled on individual index cards or Post-it® notes; one item to each card or note. The barriers and promoters must be stated succinctly (seven or fewer words is best), using a noun and a verb (e.g., a promoter: *"Celebrate the completion of every task."*). each student is responsible for coming to class with at least 10 Promoters of team Success and at least 10 Barriers to Team Success.

When students meet in teams, the process development of a set of team Norms proceeds through the following process:

- Team roles are assigned
- The Boggle® process is used to eliminate duplication of promoters and barriers
- Modified Multi-Voting is used to prioritize the lists
- One at a time, a promoter, then a barrier is selected from the list
- Potential Norms are developed achieve the promoter or prevent/alleviate the barrier
- Potential Norms are refined into a set of Team Norms accepted by Consensus decision of the Team.

Team Norms and Communication

It is important that the team members have roles. The facilitator should check to make sure the roles while monitoring team progress during the activity. Each team needs to have a **leader**, **recorder**, **encourager**, **time keeper**, perhaps a **devil's advocate**.

The Boggle® method is a good way to eliminate duplicated ideas. In this method, a team member reads aloud her Post-it® notes or cards. The other team members eliminate any of their Post-it® notes or cards that duplicate what has been read. Once the first team member has gone, then the second team member reads *his* cards and the remaining members eliminate any duplicates remaining in their Post-it® notes or cards. This continues until all members have read their list, and the remaining list contains no duplicates.

Modified Multi-voting (see page K-15) is a good technique to be use to prioritize of a number of options. It is helpful when:

1. the team disagrees on the impact of the options
2. a limited number of options can be implemented
3. there is a need to easily prioritize the options

This method works because there is no discussion (justification) for the votes. It almost always turns out that the top priority items rise to the top for a variety of reasons. This voting eliminates all discussion on items that are of little importance. The voting part of the multi-voting process really does need to be done silently for maximum effectiveness. Discussion is reserved for the top-priority items

In the last stage of norm building, teams select one topic at a time from their lists and then develop ways to **encourage the promoters** and **reduce the barriers** to effective teams. For each promoter selected, teams develop an operational statement of a team norm (an action, response, or behavior) that will be used to achieve the desired result. For each barrier selected, teams develop a set of actions, responses, or behaviors that will:

- ✓ ensure that the barrier does not occur (prevention)
- ✓ eliminate the barrier if it does occur (mild intervention, contingency plan)
- ✓ (What Kepner-Tregoe tool is this related to?)

'Operational' Team Norms Example

Be on time for team meetings!

Versus

Be

**at the designated meeting location,
at the time specified in the agenda,
in your seat with your elbows on the table,
with a pencil or pen in your hand ready to write,
with a note pad on the table,
with the agenda and other materials for the meeting to
the right of the note pad, and
in eye contact with the Team Leader!**

**(Can an 'average person' use this checklist to determine
if a team member is 'on time'?)**

The team repeats this process with the top priority items on the barriers and promoters lists, and continues to refine the norms into a Code of Cooperation. In ECE 100, Development of a Team Code of Cooperation is one of the expectations required of every team; a copy is placed in the team's Design Notebook. When students request intervention from course instructors to deal with conflict within their team, the first thing the instructor will ask is how the team's Code of Cooperation might be relevant to the particular issues causing the conflict.

SECTION I

Assessment, Levels of Learning, Degrees of Internalization

The slides in this section are used to introduce assessment; i.e., *'how much do you know'* and *'how well do you know it'*. The presentation as given here lasts about 100 minutes and includes an active learning jigsaw exercise followed by class discussion. Competency matrices are introduced as a part of this presentation. The material in this section is rather general; assessment is discussed in more detail in Section J, which also contains the reading material used for the jigsaw included in this session.

More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.

Levels of Learning (LoL) and Degrees of Internalization (DoI)

◆ Cognitive Domain (thinking, intellect) ¹

- Knowledge
- Comprehension
- Application
- Analysis
- Synthesis
- Evaluation

¹ Bloom et al. 1956

◆ Affective Domain (attitude, feelings) ²

- Receiving
- Responding
- Valuing

² Krathwohl et al. 1964

I- 2

Why are we learning this?

- ◆ Industry has made it clear to the education community: they want life-long learners. This material will provide a model for you to help you *structure your own future learning*,
i.e., **succeed.**
- ◆ This material, if taken seriously, will significantly enhance your success in your other courses.

I- 3

What Do You Know?

1. Do you know the symbol used for oxygen ?
2. Can you balance the following chemical reaction ?
$$\text{O}_2 + \text{H}_2 \text{-----} \rightarrow \text{H}_2\text{O}$$
3. Do you know the valence for oxygen ?
4. Do you know the orbit or spin direction of oxygen's unpaired electrons ?
5. Can you write down and explain the half reactions that are associated with the above reaction ?
6. Can you propose several processes for the creation of methyl alcohol (methanol CH_3OH) from oxygen and other substances; then select one using criteria that you develop and justify ?

I- 4

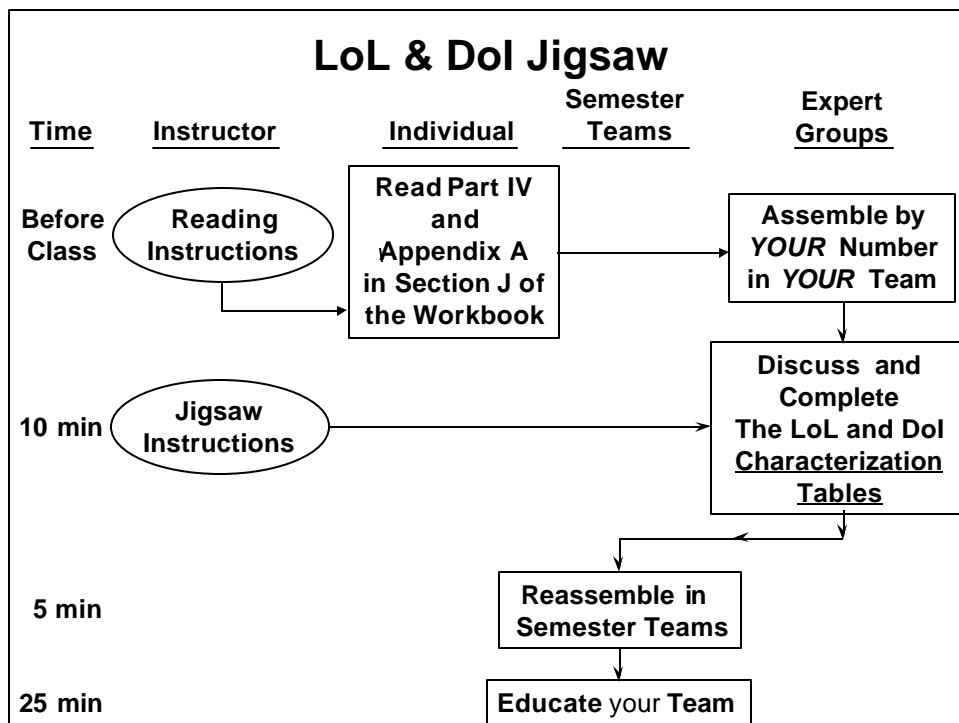
What Is Your Attitude?

1. How do you react when I tell you that all the molecular oxygen in our atmosphere is O_5 ?
2. How do you react when I tell you that the atomic weight of oxygen (O) in AMU's is 159? 14? 16?
3. How do you react when I tell you that the unpaired electrons for oxygen are in the 2p orbital?
4. How do you react when I tell you that oxygen can be generated from moon rocks?
5. How do you react when I tell you that the Apollo 13 explosion involved not being able to drain the liquid oxygen tank?

I- 6

LoL and DOI Sequence

- ♦ Are you willing to RECEIVE the information?
 - ä Yes! Listen to a lecture, read the assignment, etc.
 - ä You can demonstrate Knowledge LoL !
- ♦ Are you willing to RESPOND and use the information?
 - ä Yes! Solve a problem, take a test, etc.
 - ä You can demonstrate Comprehension LoL !
- ♦ Do you VALUE and remember the information?
 - ä Yes! Without being told to do so, use the information to solve a problem, take a test, etc.
 - ä You can demonstrate Application LoL !



Becoming an 'Expert' (10 min)

Use both sides of the ***“Level of Learning & Degree of Internalization Table”*** . . .

- ◆ In the **BLANK BOXES** in column # 2, enter as many characteristics of your assigned LoL and **Dol** as you can.
- ◆ In the **BLANK BOXES** in column # 3, enter as many unique characteristics of your assigned LoL and Dol as you can (i.e., characteristics that are not shared with the lower LoL and Dol).

I- 11

Teaching Your Team (17 min)

Starting with the Knowledge LoL 'expert' and ending with the Analysis LoL 'expert', each LoL 'expert' presents (in ~ 2 minutes!)

1. what characterizes their LoL and
2. the unique characteristics of their LoL that are not shared with the next lower LoL.

Each team member enters this information as it is presented in their **LoL DEFINITION Table**.

Repeat this process for the Dol's

I- 12

Level of Learning & Degree of Internalization Characterization Table

EXPERT TABLE # _____

1. In **column # 1** enter Your Expert Table's assigned **Level of Learning** (LoL) and **Degree of Internalization** (DoI).
2. In **column # 2**, enter as many characteristics of your expert table's assigned LoL and DoI as you can.
3. In **column # 3**, identify and enter the characteristics of your expert table's assigned LoL and DoI that are unique (i.e., characteristics that are not shared with the next lower LoL and DoI).

1. WORK AT	2. IS CHARACTERIZED BY . . .	3. IS MORE THAN _____ LoL BECAUSE . . .
LoL _____ 		

1. WORK AT	2. IS CHARACTERIZED BY . . .	3. IS MORE THAN _____ DoI BECAUSE ...
DoI _____ 		

***Level of Learning (LoL)* DEFINITION TABLE**

Starting with the **Knowledge** LoL 'expert' and ending with the **Analysis** LoL expert, each LoL 'expert' presents:

1. what **characterizes** their LoL and then
2. **identifies** the **characteristics** of their LoL that are **unique** (i.e., characteristics that are **not shared** with the **higher** LoL).

Each student should **enter this information** in **their** personal copy of this **table** as it is presented by the expert.

WORK AT	IS CHARACTERIZED BY		BECAUSE IT <i>LACKS</i> THE FOLLOWING . . .
Analysis LoL		Work at <i>application LoL</i> is NOT at <i>analysis LoL</i> . . .	<u>unique</u> features of <i>analysis LoL</i> :
Application LoL		Work at <i>comprehension LoL</i> is NOT at <i>application LoL</i> . . .	<u>unique</u> features of <i>application LoL</i> :
Comprehension LoL		Work at <i>knowledge LoL</i> is NOT at <i>comprehension LoL</i> . . .	<u>unique</u> features of <i>comprehension LoL</i> :
Knowledge LoL		Work at <i>(unaware)</i> is NOT at <i>knowledge LoL</i> . . .	<u>unique</u> features of <i>knowledge LoL</i> :
Unaware	does not understand what is being discussed, has never heard the terms before		

***Degree of Internalization (Dol)* DEFINITION TABLE**

Starting with the **Receiving** Dol 'expert' and ending with the **Valuing** Dol expert, each Dol 'expert' presents

1. what **characterizes** their Dol and
2. **identifies** the **characteristics** of their Dol that are **unique** (i.e., characteristics that are **not shared** with the **higher** Dol).

Each student should **enter this information** in **their** personal copy of this **table** as it is presented by the expert.

WORK AT	IS CHARACTERIZED BY		BECAUSE IT <i>LACKS</i> THE FOLLOWING . ..
Valuing Dol		Work at <i>responding</i> Dol is NOT at <i>valuing</i> Dol . .	<u>unique</u> features of <i>valuing</i> Dol:
Responding Dol		Work at <i>receiving</i> Dol is NOT at <i>resopnding</i> Dol . .	<u>unique</u> features of <i>responding</i> Dol:
Receiving Dol		Work at <i>(unaware)</i> is NOT at <i>receiving</i> Dol . .	<u>unique</u> features of <i>receiving</i> Dol:
Unaware	does not understand what is being discussed, has never heard the terms before		

Mechanics Problem Review (4 min)

- ◆ Quickly review the 'Simple Mechanics Problem' on page J.67 in the Orange Workbook and the three solutions on pages J.68 to J.71.
- ◆ As you read the solutions:
 - note the general form and content of the three solutions.
 - do NOT evaluate the 'technical correctness' of the solutions.

Practice Assessment (Instructions)

Each student get out the blue (then green , then pink) Work Product Assessment Examples.

1. Discuss the blue form with your team.
2. Use the green form to assess the second solution (confirm that your analysis is consistent with the UNIQUE FEATURES in the Definition Tables your team developed .
3. Use the pink form to assess the third solution (confirm that your analysis is consistent with the UNIQUE FEATURES in the Definition Tables your team developed.

Practice Assessment (12 min)

To complete the Work Product Assessment Template,

1. review the work product (first, second or third solution) using the
Level of Learning Definition Table;
2. select the appropriate LoL,
3. circle that LoL in the first column,
4. enter the reasons in the fourth column,
5. circle the next lower LoL in the second column,
6. enter the reasons that the work product is
more than this lower LoL in the fourth column,
7. circle the next higher LoL in the third column,
8. enter the reasons the work product is
less than this higher LoL in the fourth column.

Level of Learning (LoL) WORK PRODUCT ASSESSMENT EXAMPLE

Work Product: ***First Solution to a Simple Mechanics Problem***

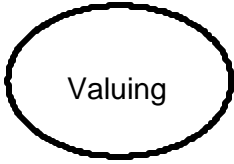

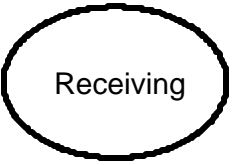
To complete this table, **1) review** the work product using the **Level of Learning Definition Table**, **2) select** the **appropriate LoL**, **3) circle** that LoL in the **first** column, **4) enter the reasons** in the **fourth** column, **5) circle** the **next lower LoL** in the **second** column, **6) enter** the **reasons** that the work product is **more than** this **lower LoL** in the **fourth** column, **7) circle** the **next higher LoL** in the **third** column, and **8) enter the reasons** the work product is **less than** this **higher LoL** in the **fourth** column.

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Synthesis	Synthesis	Synthesis	
Analysis	Analysis	Analysis	
Application	Application	Application	
Comprehension	Comprehension	Comprehension	The person may be at Comprehension LoL (i.e., they solved a problem) but the accompanying documentation does not support Comprehension LoL. The context does not contain anything about learning objectives nor is there any substantive description of the solution method .
Knowledge	Knowledge	Knowledge	The person has done more than define terms or identify the applicable conservation principles. This person has solved the problem using a recognized pattern; i.e., used an example problem on page 140 and revised the numerical values .

***Degree of Internalization (Dol)* WORK PRODUCT ASSESSMENT EXAMPLE**

Work Product: ***First Solution to a Simple Mechanics Problem***

To complete this table, 1) review the work product using the ***Degree of Internalization Definition Table***, 2) select the **appropriate** Dol, 3) circle that Dol in the **first** column, 4) enter the **reasons** in the **fourth** column, 5) circle the **next lower** Dol in the **second** column, 6) enter the **reasons** that the work product is **more than this lower** Dol in the **fourth** column, 7) circle the **next higher** Dol in the **third** column, and 8) enter the **reasons** the work product is **less than this higher** Dol in the **fourth** column.

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Valuing	Valuing		There is nothing in the work products that suggests this person is doing more than just submitting an assignment. There is no sense of accomplishment, no exclamations of enjoyment. There is no sense that this person recognizes conservation principles as a potentially useful tool or concept
	Responding	Responding	The person has completed the assignment and submitted a solution. There is no indication that the person achieved any satisfaction from completing the assignment. In fact, the lack of any substantive context suggest this probably represents the lowest level of responding (i.e., agreeing to respond)
Receiving		Receiving	The person has clearly done more than read about or listen to lectures on conservation principles.

Level of Learning (LoL) WORK PRODUCT ASSESSMENT TEMPLATE

Work Product: ***Second Solution to a Simple Mechanics Problem***

To complete this table, **1) review** the work product using the ***Level of Learning Definition Table***, **2) select** the **appropriate** LoL, **3) circle** that LoL in the **first** column, **4) enter the **reasons** in the **fourth** column**, **5) circle** the **next lower** LoL in the **second** column, **6) enter** the **reasons** that the work product is **more than** this **lower** LoL in the **fourth** column, **7) circle** the **next higher** LoL in the **third** column, and **8) enter the **reasons** the work product is **less than** this **higher** LoL in the **fourth** column.**

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Synthesis	Synthesis	Synthesis	
Analysis	Analysis	Analysis	
Application	Application	Application	
Comprehension	Comprehension	Comprehension	
Knowledge	Knowledge	Knowledge	

Degree of Internalization (Dol) WORK PRODUCT ASSESSMENT TEMPLATE

Work Product: ***Second Solution to a Simple Mechanics Problem***

To complete this table, **1) review** the work product using the ***Degree of Internalization Definition Table***, **2) select** the **appropriate** Dol, **3) circle** that Dol in the **first** column, **4) enter the reasons** in the **fourth** column, **5) circle** the **next lower** Dol in the **second** column, **6) enter** the **reasons** that the work product is **more than** this **lower** Dol in the **fourth** column, **7) circle** the **next higher** Dol in the **third** column, and **8) enter the reasons** the work product is **less than** this **higher** Dol in the **fourth** column.

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Valuing	Valuing	Valuing	
Responding	Responding	Responding	
Receiving	Receiving	Receiving	

Level of Learning (LoL) WORK PRODUCT ASSESSMENT TEMPLATE

Work Product: ***Third Solution to a Simple Mechanics Problem***

To complete this table, **1) review** the work product using the **Level of Learning Definition Table**, **2) select** the **appropriate LoL**, **3) circle** that LoL in the **first** column, **4) enter the reasons** in the **fourth** column, **5) circle** the **next lower** LoL in the **second** column, **6) enter** the **reasons** that the work product is **more than** this **lower** LoL in the **fourth** column, **7) circle** the **next higher** LoL in the **third** column, and **8) enter the reasons** the work product is **less than** this **higher** LoL in the **fourth** column.

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Synthesis	Synthesis	Synthesis	
Analysis	Analysis	Analysis	
Application	Application	Application	
Comprehension	Comprehension	Comprehension	
Knowledge	Knowledge	Knowledge	

Work Product: **Third Solution to a Simple Mechanics Problem**

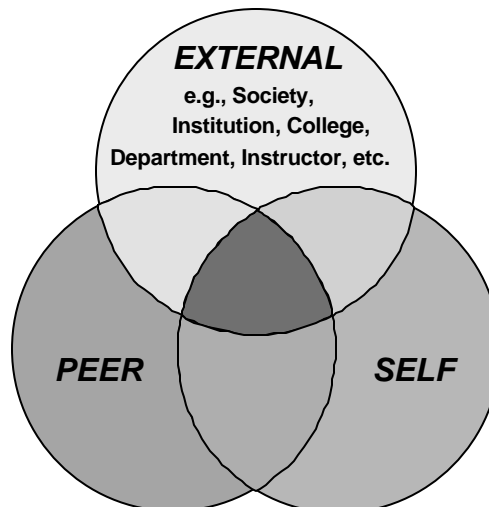
To complete this table, 1) review the work product using the **Degree of Internalization Definition Table**, 2) select the **appropriate** Dol, 3) circle that Dol in the **first** column, 4) enter the **reasons** in the **fourth** column, 5) circle the **next lower** Dol in the **second** column, 6) enter the **reasons** that the work product is **more than** this **lower** Dol in the **fourth** column, 7) circle the **next higher** Dol in the **third** column, and 8) enter the **reasons** the work product is **less than** this **higher** Dol in the **fourth** column.

IS	IS HIGER THAN	IS LOWER THAN	EXPLANATION
Valuing	Valuing	Valuing	
Responding	Responding	Responding	
Receiving	Receiving	Receiving	

Assessment of Work Products

- ◆ What characteristics of the work can you assess ?
 - is the work well presented ?
 - is the work well organized ?
 - is the work technically correct ?
 - what LoL or DoI does the work demonstrate ?
 -
- ◆ What work products can you assess ?
 - homework assignments
 - portfolios
 - design notebooks
 - reports
 -

Assessment Domains



Design Notebook Competency Matrix

ECE 100 Design Notebook Competency Matrix

Name:

Last Update 3/14/96 10:53 AM

The letters in each box indicate in which session(s) of the class the competency could be achieved: C = Concepts, M = Modeling, and L = Laboratory. Grayed boxes show levels that are not expected: i) to be achieved or ii) to have work products in the Design Notebook for support. Bullets show levels already achieved.

ECE 100 Design Notebook Competency Matrix				Affective Objectives			Cognitive Objectives					
Name:		The letters in each box indicate in which session(s) of the class the competency could be achieved: C = Concepts, M = Modeling, and L = Laboratory. Grayed boxes show levels that are not expected: i) to be achieved or ii) to have work products in the Design Notebook for support. Bullets show levels already achieved.		Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Last Update	3 / 14 / 96 10 : 53 AM	Competencies (bolded competencies are required)	Number ¹									
4 Creative Problem Solving	Getting Started (continued) (Chapter 2)	Problem Solving Heuristic	# . # - ##	•			•					
		Define (Problem)	# . # - ##	•			•					
		Generate (Alternatives)	# . # - ##	•			•					
		Decide (Course of Action)	# . # - ##	•			•					
		Implement (Solution)	# . # - ##	•			•					
		Evaluate (Process)	# . # - ##	•			•					
		Inter Personal Interactions	# . # - ##	■			•					
		Customer	# . # - ##	■			•					
		Teams	# . # - ##	■			•					
	3 Problem Definition (Chapter3)	Collect Data	# . 3 - ##	•	•		•	L	L			
		Current State - Desired State	# . 3 - ##	•	•		•	L	L			
		Dunker Diagram	# . 3 - ##	•	•		•	L	L			
		Functional Solution	# . 3 - ##	•	•		•	L	L			
		Specific Solution	# . 3 - ##	•	•		•	L	L			
		Evaluate the Problem Definition	# . 3 - ##	•	•		•	L	L			
		Explore Problem	# . 3 - ##	•	•		•	L	L			
		People Involved	# . 3 - ##	•	•		•	L	L			
		Source of Problem	# . 3 - ##	•	•		•	L	L			
		Statement/Restatement	# . 3 - ##	•	•		•	L	L			

Determining the LoL (3 min)

- ◆ We will use your Team Design Notebooks to illustrate the process of determining LoL/Dol for ECE 100 work products.
- ◆ Please get out your Design Notebooks!
- ◆ Locate your team's work products for the Problem Definition portion of Project #1.
N.B.: do NOT evaluate 'technically correct'!
- ◆ Using the LoL Definition Table your team just created, each team determine the highest LoL demonstrated by these work products.

Filling In The Matrix (7 min)

- ◆ Open your notebooks to the Competency Matrix.
- ◆ What page in the matrix that has Competencies that match the work done for Project #1 Problem Definition ?
- ◆ Find the Duncker Diagram you did for Project #1 Problem Definition.
- ◆ If not completed already, enter the page number for the Duncker Diagram in the white box at the intersection of row Duncker Diagram and column Comprehension LoL.
- ◆ Fill in as many other Comprehension LoL boxes for Problem Definition as you can.

Assessment Process (A Review)¹

- ◆ Step 1 (specified for this course)
Define the Assessment Exemplars (LoL & DoI)
- ◆ Step 2
Compare the work product with the Exemplars and select the Exemplar that has the best match
- ◆ Step 3 (optional Reflection Logs)
Explain, in writing, why the Exemplar selected in step 2 was selected
- ◆ Step 4
Determine the appropriate competency and update the Competency Matrix

¹see Part IV in *A Guide to Presentation, Organization, and Assessment* in Section J

SECTION J

A Guide to Presentation, Organization and Assessment of Technical Work

The material in this section is related to the presentation, organization, and assessment of technical work products. This material is divided into several parts and should **not** be read in 'one sitting'; however, students should read **all** of the parts and read them in the order presented.

Part **I** defines the **faculty expectations** for the presentation of technical work products; students should read this material carefully and use it as a guide for preparing work products in ECE 100. Students whose work product fail to meet expectations should reread this material and discuss it with colleagues and the ECE 100 faculty.

Part **II** describes **how to organize** a collection of different, but interrelated, work products. It is almost exclusively a '*how to do it*' section; students should follow the suggested steps when creating team design notebooks or personal portfolios.

Part **III** introduces the idea of an assessment **checklist** and explains how to use these checklists to evaluate whether the work is complete (i.e., the work will meet the instructor's expectations). Two examples, showing how the checklists are used, are provided.

Part **IV** addresses **assessment**. Competency matrices (what they are, how they are created, how they are completed) are discussed in some detail. The material is designed to help students develop the ability to recognize different levels of learning in work products prepared by other people (as well as their own work products). This material may be difficult to understand; students often need to revisit it several times while assessing technical work products and using competency matrices.

**A Guide
to
Presentation, Organization, and Assessment of Technical Work
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Preface

One aspect of self-regulation (see Section B) is the ability to assess ***where you are*** so you can decide ***what you should do next***. Knowing ***where you are*** involves a number of issues, one of the more important being knowing ***what you know*** and ***how well you know it***. Once you know “***what you know***” and “***how well you know it***” (i.e., know your level of learning on a topic), you can use this information to determine what additional learning might be appropriate.

Self assessing your state of knowledge is difficult and requires practice. Before taking up the issue of how to assess your level of learning, which is covered in Part IV of this guide, it was felt necessary to first cover three other topics: Presentation of Work (Part I), Organization of Work (Part II), and Assignment Expectations & Assessment Using Checklists (Part III). These three topics should help you better understand what the faculty expect from you and show you how the “experts” (i.e., the faculty) do assessment. By understanding how experts do assessment it is hoped you will learn how to self assess your work products.

Acknowledgments

The material presented in Part IV of this Guide is a compilation of the thoughts and experiences of a number of faculty at A.S.U. who have used competency matrices to assist in evaluating student performance in their classes during the last several years.

LB & BWMcN

Part I -- Presentation of Technical Work

Before discussing how to organize and then assess your technical work, it is necessary to generate and present some work. You have, of course, had experience in this area¹; you have also, no doubt, had situations where the evaluation of your submitted work was lower than anticipated, in part at least, because the work, while technically correct, was not presented well (in the eyes of the assessor). Your ability, and that of others, to assess your work depends, to a large extent, on how you choose to present (i.e., document) your work. Much of the evaluation process is directly related to the quality of the presentation, which is based on the evaluator's expectations. You must understand what is expected in order to provide it.

Part I of this document presents some general presentation expectations that apply to all work products. This is followed by specific expectations for a variety of different work products (e.g., homework, project work, graphic material, plots, mathematical models, and reports).

General Presentation Expectations for Work Products

Historically, given an assignment, you most likely did not spend much time thinking about how to present your work; you just did the assignment and turned it in. While such an approach may be satisfactory (i.e., successful) some of the time, such an approach cannot be relied on to consistently generate quality work products. Luckily there are some fairly simple things you can do to enhance your chances of creating quality work products. A review of a number of successful work products reveals that quality work products generally:

- have a common general overall pattern of organization, and
- incorporate a number of common characteristics or traits.

The organizational pattern and common traits are discussed below. As you prepare your work products you will want to embrace as many of these items as you can.

An Organization Heuristic - *The Presentation Sandwich*

It may seem a bit strange at first that the overall organization of your work is something that you need to consider as you prepare your work products; but it is. Virtually all quality communication, whether written or oral, has the same overall organizational pattern. In fact the pattern is so ubiquitous and expected, that when the pattern is absent the work is often assessed lower than the content might suggest.

The expected general pattern is quite simple and consists of three parts:

- the front material, which has the one, overriding purpose of Orienting the Reader to the work,

¹ During high school and college you have done homework, generated reports, etc. that were submitted to a teacher for evaluation (grading).

Part I - Presentation of Technical Work

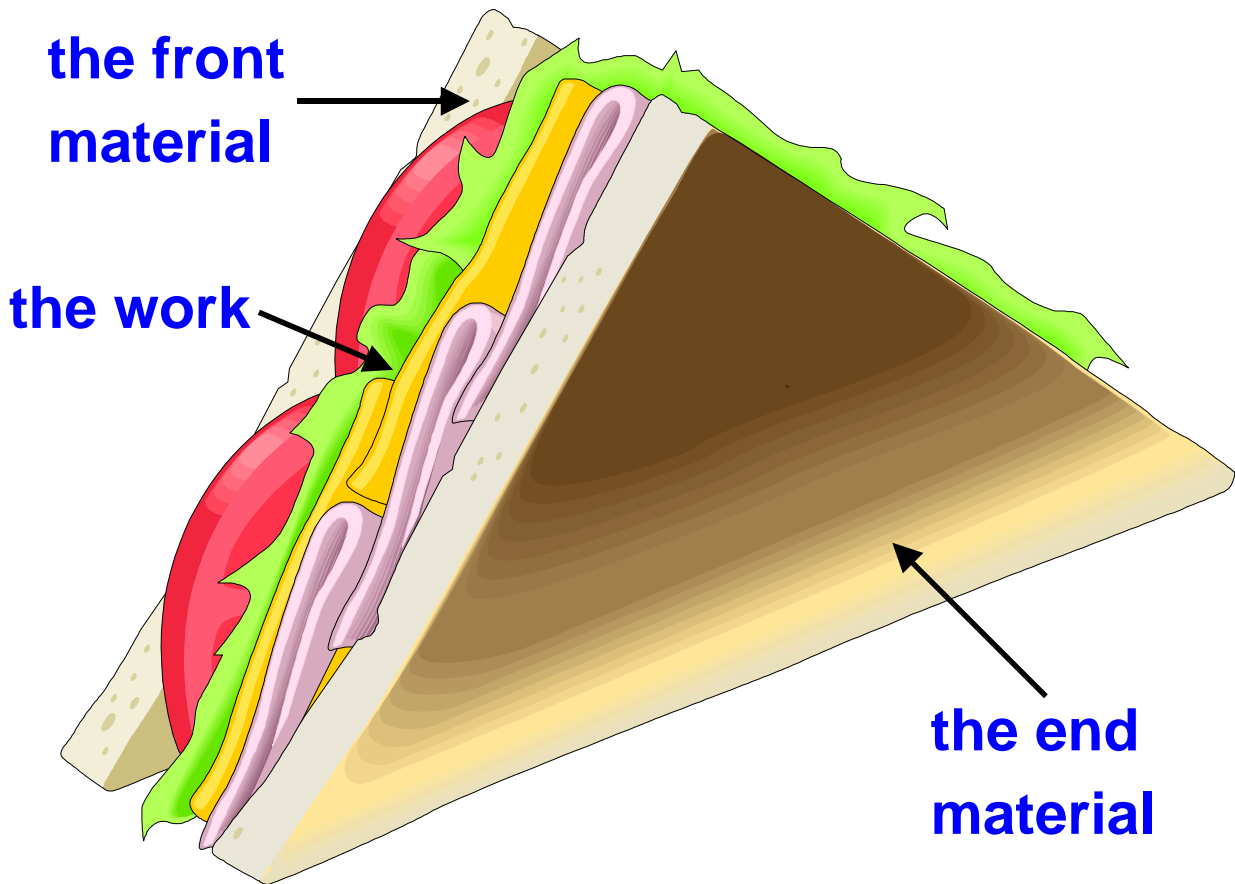


Figure 1 - The Presentation Sandwich

- the work, which is the technical content of the work product, and
- the end material, which reviews or reflects on the work.

This structure is shown pictorially in Figure 1 as the Presentation Sandwich. In this sandwich the front and end materials are the pieces of bread holding the work (i.e., the tomatoes, lettuce, cheese and salami) together. Just as a sandwich is not just the filling, so the presentation of technical work is not just the work. You need to add the two slices of bread.

These *slices of bread* take on different names depending on the type of work product you are preparing. For homework and design project work, the front material is often referred to, as the **Context** while the end material is known as the **Discussion** or **Reflection**. For oral reports, written reports, memos, etc. the front material is often referred to as the **Introduction** and the end material as the **Summary** or **Conclusion**.

When preparing the sandwich remember:

1. Put the slices physically around the filling, i.e., the order of the presentation is the front material (e.g., the **Context**) followed by the work which is followed by the end material (e.g., the **Discussion**).
2. Keep the parts of the sandwich clearly distinct so that when you look at the work product you can clearly distinguish the front material from the work and the work

Part I - Presentation of Technical Work

from the end material. Inserting an appropriate heading at the start of the work² and end material generally accomplishes this demarcation. No heading is generally required or expected for the front material.

You may find the second item a bit difficult at times as you try to decide whether some material (e.g., the description of the calculation process) orients the reader and belongs in the front material or is part of the work. In such cases the best thing to do is probably to put the material in both places, redundancy is not forbidden and can enhance the overall quality of the work product.

This expected overall organization requires some extra work, work that seems to be solely associated with the need to make the work understandable to someone other than you. The benefits to you may not be obvious. But there are benefits. When you do this *extra* work, you often actually achieve a better understanding of what you have done (are doing). With this better understanding comes the ability to improve the work and receive a higher assessment on the assignment.

Common General Presentation Goals

In addition to the expected general pattern of organization, there are other general presentation goals that enhance the quality of a work product. When preparing your technical work you should strive to:

1. orient the reader

It is crucial that you let your reader (or yourself) know what is coming, what to expect. You must let the reader know what sort of technical work, what sort of results, will be found in the following pages. You must inform the reader how the work is organized. Telling the reader why you did the work can help establish the desired point of view when the work is reviewed. Orienting your reader is a goal not just for the front material but also applies to the work portion of the work product.

2. explain the process

You should keep the reader informed of the process used to generate the work. This means explaining what is being attempted, why it is being attempted, and what method is being used. This also means that you explain the consequences or meaning of your work. These explanations could be in any of the three general parts of the work product.

3. make explanations clear

Explanations are generally clear to you but what about from the reader's or assessor's point of view? Clarity is often difficult to achieve, in part because of the existence of multiple realities (i.e., two entirely different, honest views of the same phenomena). Using sketches, plots, figures, or some other graphical presentation to augment the text often enhances clarity. Clarity is also improved when terms and variables are defined. To determine how *clear* your work product is, try having a peer review your work.

² A heading of *The Work* is not very descriptive and should be replaced with words that describe the work, e.g., Concept Selection or Energy Balance Calculations.

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4. make the work readable

If you make the work easier to read you will improve the quality of the presentation. Explaining the process clearly improves readability. Other ways to improve readability include providing neat work, clean sketches, numbering the pages, binding the material so that it does not fall apart and yet is easy to access, etc.

5. make it clear who did the work and when the work was done

It should always be clear who did the work and when the work was done. This can be accomplished by dating and initialing each sheet of the work product.

6. make it clear that the work has ended

When the work product involves several different tasks (e.g., several homework problems, consecutive design tasks) it should be clear when you have reached the end of each task. The reader expects some type of End of Task marker. This marker could be a discussion of the work, a reflection on the work, or a summary of the work. In other words it should be clear to the reader or assessor when she has reached the end material.

While it may be difficult to achieve a high degree of success in achieving all these goals, failure to address even just one of the goals reduces your chances of producing a quality work product.

Specific Presentation Expectations for Some Types of Technical Work

In addition to the general expectations, which apply to all your work there are often additional requirements for specific types of work. The presentation expectations discussed in this section are limited to the following work products: homework, graphical material, plots, and mathematical and computer models. There is a very brief coverage of reports. If you are reading this guide for the first time you may want to skip the material on models and come back to it at a later time.

Homework Assignments

You have homework in every engineering class that you take. While you might think that since the instructor assigned the homework there is little or no need to have any front or back materials for your work product, this is not true for two important reasons.

1. While the work was assigned by the instructor that does not mean she remembers exactly what was assigned. A good orientation and discussion always helps the assessor do a more complete, quality job.
2. Preparing the front and back materials has a profoundly positive impact on what you learn in doing and preparing the work product.

The following three step process is recommended for all homework assignments. In homework assignments the front material will be called the **Context** and the end material will be called the **Discussion**.

Step 1 - Set the Context For The Work

It is important to explain what is coming, i.e., set the context for the work (general goal 1). Following Stephen Covey's admonition to "Begin With The End In Mind", the

Part I - Presentation of Technical Work

context should be **written before** you actually do the work. Writing the Context will help you focus your thinking about what you are about to do. There is no fixed way to write a Context but several questions you might consider addressing are:

- explain why the work will be done (e.g., “This is a homework assignment on equilibrium” or “This work on frame weight will be undertaken to get a better idea about how much this Home Exercise Machine might weigh”), or
- tell what will be accomplished when the work is done (e.g., “After this assignment is completed I will have shown that I know how to do force balances and that I will be prepared for the upcoming quiz” or “When this work is completed we will know the frame weight”), or
- tell how this work fits into a bigger problem (e.g., “This is the third assignment from Chapter 3” or “Estimating the cost of the Home Exercise Machine requires knowing the weight of the machine’s frame which will be determined in the following work”).

Step 2 - Do the Work

What actually goes here will vary and there may be some overlap with Context material but the following items are generally expected:

- sign and date your work (see general goal 5)
You should get into the habit of signing (at least initialing) and dating **all** work that you do where *all* means **every page** of your work.
- appropriate diagrams or sketches (see general goal 3)
The diagrams should present the information given in the problem as well as what is required. Thus, if the problem were “determine how much force it would take to lift a car using a lever and fulcrum (pivot)”, then your diagram would show the lever, the fulcrum, the car, and you pushing down on the lever.
- a description of your analysis process (see general goal 3)
Describe in a few sentences what process, methods, and approaches you plan to use in analyzing the problem; you should include any assumptions you have made. For example, in the car/lever problem, you might report that you are going to use a force balance (or equilibrium). Your description of the process should be more detailed than just stating a general name (e.g., force balance); you should describe a few of the key steps in the process selected.
- the analysis
Using the analysis process you described above, work the problem. Working the problem includes presenting all of your analysis, including all appropriate intermediate results. Note that presentation of the analysis process (working the problem) is as important as the final result (sometimes known as the answer) obtained from the analysis.
- plots and tables
In the course of doing your analysis you may generate a table and/or plot, or even a series of tables and/or plots. It is never acceptable to just generate the tables and/or

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plots and not discuss them. Clarity (general goal 3) requires that the reader know your point of view about what the tables and/or plots show. This type of discussion is part of the work. This discussion may be repeated in the end material but generally such discussion should not be found only in the end material (also see Graphic Materials on page J - 9).

Step 3 - Discuss the Results of Your Analysis

After you have completed the work you must contemplate or reflect on your results and analysis process and present comments and conclusions. You might consider commenting on:

- what was learned (e.g., “The frame weight was 34 kilograms which is much lighter than any machine we have found in the stores” or “This antenna surface area of 20,00 m² is huge, about a third of a football field”), or
- the analysis process used in working the problem (e.g., “I could not work this problem until I realized I could replace 1 with $\sin^2(\Theta) + \cos^2(\Theta)$ ” or “Until we simplified the frame, we were not able to get our model to converge”), or
- the correctness of the result (e.g., “The answer to this problem is 14.6 m², which matches the answer in the back of the book” or “This weight of 34 kilos, while it seems light, is probably correct; the model was checked using example problem 4.5 in Shigley”), or
- what will happen next (e.g., “Now we can calculate the cost of our device” or “This is the fifth problem that I have been able to work and I think I am now ready to take tomorrow’s mid term exam”).

Since the discussion is **written after the work has been completed**, you should not include any new work or analysis in the discussion; complete whatever analysis has to be done, get your answer and then write the discussion.

An example of presenting technical work using this *Presentation Sandwich* is shown in Figure 2. All three parts of the sandwich are present and obvious. The first paragraph (no heading) is the **Context** and it tells the reader that Problem Definition type analysis work is about to be done and says why the task is being undertaken (“to have a good understanding of the problem”). The work (labeled as *Determining the Present and Desired States*) consists of a brief explanation of the process to be used (“Present State Desired State method”) followed by three applications of the method. Finally the last part of the sandwich, the **Discussion**, is clearly shown with a heading. The discussion reflects back on what was done and draws a conclusion (“will not create a Duncker Diagram”) and suggests the next step. The discussion refers to specific items in the work (“recruitment/retention”).

Part I - Presentation of Technical Work

BWMcN 6/12/97

Before developing this proposal to request funding from NSF, I want to have a good understanding of the problem I plan to tackle; thus, I need to do some Problem Definition work.

Determining the Present and Desired States

I am going to use the Present State Desired State method. I am not sure whether I will need to do a Duncker Diagram and will decide after the Present State Desired State analysis is complete.

First Cut

Present State	Desired State
not enough BS engineering graduates	enough engineering graduates

These two states match in the sense that all problems in the Present State are addressed in the Desired State and there is nothing in the Desired State that is not in the Present State; however, this does not really seem to be getting at the heart of the problem. It is a bit superficial.

Second Cut

Present State	Desired State
not enough BS engineering graduates	increased graduation rate

This is maybe better; the Desired State is a bit more specific; however, I don't think the two states now match. The Desired State is addressing graduation rates; however, this is not mentioned in Present State. I need to work on the Present State.

Third Cut

Present State	Desired State
not enough students are selecting engineering and of those who do select engineering a large fraction are dropping out of engineering before they get a degree	more students select engineering as a career giving an increase in first year enrollment and most of the students enrolled in an engineering program stay in the program and graduate as BS engineers

This is pretty good. I believe that the two states match (low attraction/increased enrollment, low retention/high retention) and I believe that I have now gotten closer to the heart of the problem.

Discussion

The problem became much more detailed in my mind as I worked through this method. My first cut had no detail; my third cut has defined some specific areas to concentrate on (recruitment/retention). I think I have defined the problem well enough to start working on some ideas for the proposal; therefore, I will not create a Duncker Diagram. My next step will be an idea generation step for achieving the Desired State.

Figure 2 - Example of Using Presentation Sandwich

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Notice that the writer has assumed that the reader knows what the Present State Desired State method is and has not bothered to explain how the process works. If you have some concerns that the reader may not know the method, you could reference material that explains the process (e.g., in this case the writer could have referred to Chapter 3 in *Strategies for Creative Problem Solving* by Fogler and LeBlanc). Also notice that the work itself includes discussion about the task. The Present State Desired State method requires analysis of the proposed two states and the analysis is shown as a discussion within the work. In other words, discussion need not all be found in the end material.

Engineering Project Work

Engineering project work is really just "homework" assignments that you make for yourself. The work is prepared by you to be assessed and used by you. Again you might think that the sandwich structure would not be necessary. But this is not true for several reasons.

1. Project engineers work on an incredible number of different tasks at the same time, spending a couple of hours on one task and then switching to another task. Without the front and back material to remind her of what she is doing and/or what she has learned, such multitasking becomes almost impossible to do.
2. While the project work is done for your use, engineers are often moved to new projects with new engineers assigned to complete the existing project. Again without the sandwich structure the new engineer has little chance of easily picking up the work at the point you left off.
3. Projects require doing more than one task and the tasks undertaken are often large and complex, requiring them to be broken down into a series of sub tasks. Part II -- Physical Organization of Technical Work (on page J - 17) explains how to build an organizing structure (i.e., a Design Notebook) for all this work. This structure is greatly enhanced when all the technical work is prepared using the Presentation Sandwich.

In preparing project work each sub task should be presented with its own **Context**, its **Work**, and its own **Discussion**. The Context and Discussion slices of the sandwich are like Velcro, allowing you to purposefully connect your work together. The Context can explain why the sub task is being done as part of the project; it can refer to previous work that suggested the sub task be done. Discussions can connect the results to various aspects of the project and can direct the reader to the next logical sub task to be undertaken.

The example shown in Figure 2 shows how this works. It is reasonable to expect to find a page of work, like that shown in the figure, as part of the work on a project. Notice how the Context and Discussion tie the work together. The Context points out that the sub task (Problem Definition) is part of a project ("developing this proposal for NSF") and seems to be the first sub task ("Before developing this proposal"). The Discussion points to the next sub task for the project ("next step will be to generate some ideas"). It is very easy to write a Context for the next sub task that pointed back to the work shown in Figure 2, connecting the two sub tasks into an organized flow of work.

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Graphic Materials

Since considerable amounts of information can be shown concisely in pictures (graphic material), you will often find it useful to include a number of graphic materials in your work products (general trait 3). The design and inclusion of graphic material is discussed in many textbooks on technical writing [1], [2]. While these textbooks recommend a number of specific goals, the successful inclusion of graphic materials basically depends on two important requirements. To be successful you **must**:

1. create complete, stand-alone graphics, and
2. discuss the graphics.

A failure to meet both of these requirements will **always** lead to a lower assessment of the quality of the work.

stand-alone graphics

Because pictures concisely contain so much information (i.e., pictures capture the essence of the material) graphic materials are frequently copied and distributed, often without the accompanying text. Since this practice is so common, it is critical, when preparing graphic material, that you prepare the graphic so that it can stand-alone. This requires you to:

1. Give each graphic a complete, descriptive title. Stay away from variable (single letter) names in the title. Also be careful to not use abbreviations and acronyms that are likely unknown to the expected viewers. Add enough text to describe the situation. For example, "T vs P" or "Temperature versus Pressure" are not acceptable titles. *T* and *P* are just variable names and what *Temperatures* and *Pressures* are you talking about? Rather, "The Change in the Nylon Reactor Temperature as the Reactor Pressure Is Decreased" gives a much better description of what the graphic is showing. Figure (caption or table) numbers are optional if the graphics are not part of a formal report (where they are required) but are strongly suggested.
2. Define all variables that are part of the graphic. Clarity is greatly increased if a variable is clearly defined. If left to the imagination of the reader *W* might be *width* or *weight* or who knows what. Defining the variables can be done with footnotes, a glossary of terms, a legend, etc.
3. Darken any light grids on the graphic. Do not rely on the grids shown on the original paper to copy. There are grid colors that do not copy (often light green or blue) or do not copy well.
4. Prepare the graphical material so that it can be reproduced. While this does not require all graphics to come off a laser printer, keep in mind that graphics produced using a hard pencil (and subsequent light lines) may not copy very well.

If you have questions about how complete a given graphic is, copy the graphic, give it to a knowledgeable peer and have her tell you what the graphic says or means. If what you hear is not what you intended, then your annotation is not complete and the graphic is not yet ready to stand-alone.

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discussing your graphics

Creating an adequate discussion of graphic materials is probably accomplished less often than any of the other documentation expectations (including using a sandwich structure). Graphic materials are virtually never discussed. At best, the graphic materials are pointed to; at worst, the materials are inserted in the work with no mention of the materials in the work or end materials.

Why is discussion of graphic materials so important? The very reason you use graphic materials (*considerable amounts of information can be shown concisely in pictures*) is also the reason discussion is mandatory. Except for the simplest graphic, because there is so much information present with a graphic, the information can be interpreted in a number of different ways depending on the viewer's point of view. Thus, if you want the viewer to understand your point of view, the discussion of the graphic must become your "voice" [3], telling the viewer what you believe are the important aspects of the graphic. You should **never** leave it entirely up to the viewer to interpret the graphic material.

What exactly constitutes an acceptable discussion? Woolever [1] discusses what it takes to write a meaningful caption for the graphic³ but captions are generally not considered to be enough discussion. Using the idea in [3] of the different levels of detail (abstraction) present in graphical material, an acceptable discussion must **explicitly** discuss:

1. some piece of elementary data, e.g., an extreme data point, the location of a fastener, etc., or
2. some piece of intermediate data, e.g., the trend of a set of data points, the parts of a sub-assembly, or
3. some piece of overall data, e.g., the relationship among sets of data points, the entire assembly

You must look at your graphic, decide which level of abstraction contains the important aspect you want the viewer to understand and then **explicitly** discuss the selected data, where **explicit** discussion requires at least:

1. naming the piece of data you are discussing and
2. saying what it is that is important about the selected piece of data.

Consider the Run Chart plot shown in Appendix B. Following are several sample "discussions" of that figure.

1. A typical run chart for a student in ECE 100 is shown in Figure X.
2. A typical run chart for a student in ECE 100 is shown in Figure X. The figure shows that the maximum weekly work load occurred in the fourth week, which is the week the first modeling assignment was due.
3. A typical run chart for a student in ECE 100 is shown in Figure X. The figure shows that the running average rose quickly to about 12 hours/week and then slowly settled

³ Page 296 in Woolever

Part I - Presentation of Technical Work

in at about 10 hours/week. The stability of the running average suggests that there is some balancing of the assignment loads given by the three different part of the course.

4. A typical run chart for a student in ECE 100 is shown in Figure X. The figure shows some rather large swings in the contiguous weekly loads (as much as 5 hours/week after the sixth week), while the running average is rather stable at about 10 hours/week. This suggests that the students are still tending to put off work (work load moves down) until the assignment is due (the work load spikes up) rather than working continuously on the assignments.

The first “discussion” is generally what you supply and is not acceptable; it does not satisfy either of the two requirements for an adequate discussion. Any of the other discussions would be acceptable. Each discussion is aimed at a different level of abstraction. Discussion 2 focuses on elementary data; discussion 3 looks at intermediate data; while discussion 4 reviews an overall point of view. Further, notice that each discussion does not just name the piece of important data; the discussion says why the data was important, gives the reasons why the data is as it is, or presents the conclusions that you want to draw from the data.

Note: the previous discussion described the **minimum** acceptable discussion requirements. There is nothing to keep you from discussing several different pieces of data on the same graphic, data that may even be at different levels of abstraction.

Plots

Plots are one of the most common graphics you will use. In addition to the general items discussed above, there are specific, standard expectations concerning the presentation of plots that you will want to be aware of and follow. You should check with whomever is going to view your plots to find out what expectations they may have but in lieu any specific instructions you should prepare your plots as follows.

1. Labeled both **axes** of the plot, including units when appropriate. The use of only a variable (e.g., V) as the label is discouraged because of the different interpretations (e.g., is V volume, velocity, etc.). Using only variables as labels is not consistent with general goal 3.
2. Mark the **divisions** for each axis. The axes' values of the plot *origin* (intersection point of axes) must be clear.
3. Plot the **dependent variable** (the variable **calculated**) on the **vertical** (y) axis and plot the independent variable (the variable that was **changed**) on the horizontal (x) axis. This expectation has ramifications concerning plot titles (see item 4).
4. Add a **descriptive title**, including a Plot or Figure number (see item 1 in *stand-alone graphics* on page J-9 for more information on titles). If variable names are included in the title give the **dependent variable first** and the **independent variable second**.
5. Use a concise, **descriptive legend** defining the various curves if you are displaying a number of related curves on the same plot.

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6. Show the experimental data points used in generating the plot. Note: data points generated by a mathematical formula are generally not shown, only the smooth curve passing through the points is shown.
7. Draw smooth curves through or near the data points to show the trend, as opposed to just showing the data points.

The above expectations are true for any plot found in your work products whether it is hand or computer generated. You may find that computer drawn plots do not meet some of these annotation expectations. In such cases it is generally permissible⁴ to add the annotation after the plot has been generated. You can add this annotation by hand, with a typewriter, or transfers.

Analytical Models⁵

Analytical models play a significant role in engineering; consequently, it is very important that you understand what is expected when presenting your analytical models. The material that follows is divided into three major areas: **1)** how to present the work related to the development of the model; **2)** what is expected concerning the model itself; and **3)** how to present the work related to the use of the model.

mathematical model development

What is expected for **mathematical** model development follows directly from the general goals. Mathematical model development concerns all aspects of assembling the set of equations that are used to predict performance. After reading the model development material it is expected that the reader will believe that the work is complete and correct. It is expected that all model development work will:

1. define the system being modeled (general goals 2 & 3),
2. define the model limitations (general goal 2),
3. define the model variables (general goal 3),
4. establish the appropriateness of the modeling method (general goal 2), and
5. establish the correctness of the model's results (general goal 2).

The first three items are relatively straightforward and probably reflect features you have already been including in your presentations. However, the fourth item may not currently be part of your presentations. The appropriateness of the modeling method for homework problems is often assumed (implicit and not stated) simply because the instructor assigned the problem. Even so, it is important to address this issue when presenting model development. There are several ways to establish the appropriateness of your model. You can cite experts. You can also construct the model from basic principles of science and mathematics. Appropriateness also requires

⁴ If the work product is part of an assignment used to demonstrate you know how to have the computer generate all the needed annotations, then adding the annotations manually is clearly not acceptable.

⁵ If you are unfamiliar with mathematical models skip this section and come back later after you start building and using mathematical models.

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addressing whether you have the necessary resources (time, money, computer power, expertise, etc.) to implement the model; i.e., applying **Occam's razor**.

The fifth item is an issue you may or may not have explicitly addressed to date. It is expected that you will present work to show that the model is actually working correctly (i.e., that there are no errors in the model). There is a variety of ways you can show that your model is working correctly, each with a different degree of credibility. Generally, the best way to show model correctness is to run your model with a test case that has known results (e.g., run a homework problem from a textbook). If this is not possible, the best method is to show that the model generates results (designs) similar to existing designs (e.g., the models predict rocket nozzle sizes of the same size as those found in industry). If neither of the above are possible, you might show that the model *behaves* correctly (i.e., when inputs are changed the outputs change in the predicted manner). Some confidence in model correctness can be obtained by showing that the model generates correct order of magnitude answers. The method least likely to convince, although it does provide some evidence of model correctness, is to show that the model reproduces the results of some earlier paper and pencil work (i.e., 'hand calculations').

computer models

The above discussion applies to any model that is developed, independent of the method or tools used in **executing** the model. Computer models require additional documentation to help assure that the computer model is understandable and correct.

high level languages

If the model is developed using a high level language such as C, the computer code must include comments and a variable dictionary. A listing of the program must be included. The listing should be easy to read (i.e., not bound into the documentation in such a manner as to make reading impossible). Any model that exceeds several hundred lines of code should be broken up into a set of smaller subroutines or procedures with an accompanying flowchart to explain the general program logic and control.

equation solvers

If the model is developed using an equation solving program such as TKSolver then the documentation must include a completed Variable Sheet⁶ including the Units and Comments Columns. The Variable Sheet must show a consistent set of values for **all** variables. You must also supply a copy of the Rule (Equation) Sheet. The Rule Sheet should contain some general comments to link major sets of equations together. There must be enough annotation on the Rule Sheet to explain the basis for the various equations or sets of related equations. If the model uses any special user defined functions these should also be included in the material submitted. User functions should be documented in the same manner as the equations on the Rule Sheet.

⁶ Equation solving programs have a variety of input and output screens called sheets. Some of these programs can solve multiple cases by running *List Solving*.

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spreadsheets

Documenting a model using a spreadsheet may be more difficult than using high level languages or equation solvers because by default spreadsheet equations use cell addresses rather than variable names. However, names can be assigned to single cells and these names can be used in the formulas in place of cell addresses. While arrays may be assigned names, the **individual** elements of the array may **not** be addressed by name. However, the array name may be used in built-in functions in place of the range. In spreadsheets, a clearly defined title or heading must be assigned to **each** column and/or row of the sheet and it may be appropriate to use an adjacent cell to identify or label the contents of an individual cell. If the equations in the spreadsheet are not *intuitively obvious*, then you should insert a *Cell Comment* in the cell containing the equation, explaining the equation. You may also want to append a report that explains what calculation is being performed in each cell.

In developing a spreadsheet model, there are some matters to consider which will generally lead to a robust, easily maintained, quality model. In particular:

1. Start with a plan. Sketch out on paper what the spreadsheet is going to look like.
2. Keep data entry and calculation areas separate. If the sheet has numerous inputs or data, you may want to have an entire screen reserved for the inputs or data.
3. Use the paper sketch cited above to construct the actual spreadsheet.
4. Concentrate the entry of your inputs or data in one area or block. Arrange the inputs or data in contiguous cells (i.e., sequential rows in a few columns, or sequential columns in a few rows).
5. Do **not** use **numerical values** for "design constants or parameters" in your formulae. Use cell references and assign names to the cells containing the current numerical values of these "design constants or parameters". This will allow you to change these values without changing the formulae. For example, enter the numerical value for the time step in a cell and use this cell reference or name in your formula for calculating time.
6. Separate, decompose, or parse large or complex calculations into a set of smaller or simpler calculations. Place the smaller or simpler calculations in adjacent or contiguous cells in the sheet.
7. Always test, validate, or calibrate your spreadsheet (see item 5 under model development).
8. Use cell protection for protecting and highlighting areas that contain formulae or other information that will not be changed frequently.
9. Use column and row labels as well as cell labels extensively. Include operating instructions for the sheet (text boxes may be used for these instructions). In summary, clearly and completely annotate your spreadsheet model.
10. Use the cell and sheet formatting features to improve the appearance and presentation of your model.
11. Back up your files FREQUENTLY! Maintain at **least two** copies of the files on **separate** diskettes (or one diskette and your hard drive)! This may appear to be a

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tedious, unnecessary, or even unproductive task; however, the first time your files are damaged or lost you will value this task immediately!

the use of models

Once a model has been developed and validated (or calibrated, shown to be correct, tested, etc.), you will be using the model to assist you in understanding a system or making decisions based on your model. You may use the model once or twice, or in some instances, you may use the model a great many times (i.e., you may execute the model for a number of design cases). It is easy to be overwhelmed by the enormity of data that can be generated with a computer model, and the presentation of this work needs careful consideration; in particular, how to display and how to discuss the results for the various 'cases'.

displaying the results

The important results of any case, such as those used to substantiate a conclusion, can be displayed using plots and/or tables. Tables are generally required for any plot shown. However, there is no need to generate plots for all the tabular data; only the most important relationships need to be plotted. The data from all cases that are executed using the same model (i.e., the equations remain unchanged from case to case; only the input data are changed) should be grouped together in some logical order (chronological, variable changed from case to case, etc.).

It is important that the numerical values of **all** the variables be known for **each** case. Generally you will have a large set of input variables that remain unchanged, and a smaller set of input variables that are changed from case to case. A listing of the variables that are held constant during a case, and their numerical values, should precede the case results. For each case that you run, you will generate a set of lists, probably collected into a table, showing how the result variables changed. For each case executed you must annotate the lists or tables of results with an explanation of what has changed from the previous case (i.e., specify the numerical values of the input variables that changed for the each case). If you use a general table containing numerous result variables, only some of which are of interest for each case, you must identify or mark the variables of interest (using a highlighting marker is acceptable or you may use spreadsheet formatting).

discussing the results

When you present the results of your work you should explicitly discuss the results (i.e., never submit a plot or a table without some discussion of the table or plot). This written discussion should generally precede the results (the tables or plots). When you develop this discussion you should review the data and then tell the viewer what you want the viewer to notice (explicit presentation); do **not** make the viewer determine (i.e., infer) what is important or interesting about the data (implicit presentation). Explain the decisions you have made or will make based on the data. If the plotted data has any anomalies, do not ignore them; either attempt to explain why they exist or admit that after consideration you cannot explain the unusual (unexpected) shape. The discussion must refer to the plots and tables by their names or numbers (see also *discussing your graphics* on page J-10).

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Reports

Up to now the work products discussed have been ones prepared by you primarily for your use, either in your project work or in your demonstration of subject mastery for a class. Reports (oral and written) have a different audience; reports are not prepared primarily for your use. You prepare reports for use by someone else. This different audience means that you need to change what goes into the front and end material. The front material (the Introduction) must indicate the scope of the work covered and give an overview of the organization (i.e., a road map) of the material in the body (i.e., the work or sandwich innards) of the report. The end material (the Conclusions) must summarize the important parts in the body of the report. An old bromide for how to give good oral reports is "Tell them what you are going to tell them; Tell them; Tell them what you told them. This is just a restating of the need for a sandwich structure for an oral report.

References

- [1] K. R. Woolever, *Writing for the Technical Professions*, New York: Longman, 1999 pp. 125 - 139.
- [2] D. G. Riordan and S. E. Pauley, *Technical Report Writing Today*, sixth edition, Boston: Houghton Mifflin Company, 1996, pp.183 - 208.
- [3] M. J. Killingsworth and M. Gilbertson, "How Can Text and Graphics Be integrated Effectively?", *Solving Problems in Technical Writing*, Ed. L. Beene and P. White, New York: Oxford, 1988, pp. 130 - 149

Part II -- Physical Organization of Technical Work

If you only have two or three items of technical work, there may be little need to spend time organizing the work; however, this is rarely the case. Classes generally have many assignments; projects require the completion of many different tasks; team projects have work authored by several different team members. If no effort is made to organize all this work, before long you have a collection of disorganized and, therefore, relatively useless, technical work products.

Organizing your work is always important. Organized work is work that can be used again. Organized work can be used to review the semester's work; it can be used to remind you how to do something a year later; it can be used to show someone else what you have done. There are many ways to organize the work (e.g., chronologically, by assignment number, alphabetically, etc.), each appropriate depending on the reason for organizing the work.

Characteristics of Organized Work

Before describing several organizing structures that you can use, it is important to know the characteristics of organized work. There are two major criteria:

1. specific, desired work products must be easy to find and
2. the work should seem to be an integrated whole (i.e., not merely a collection of unrelated tasks or topics)

The first of these is relatively easy to accomplish; you can use a table of contents, number the pages, use various indexes, and divide the work into smaller manageable pieces. For example, this workbook: a) has a Table of Contents, b) has been divided into thirteen different sections, and c) has no two pages with the same page number. How useful (i.e., organized) would this *Workbook* be if it had none of these?

Organizing the body of work into an integrated whole is a bit more difficult. This task is similar to that of developing transition paragraphs between the major sections of a report. The report can make sense without these paragraphs; however, their presence improves the quality of the report. Creating this sense of integration requires some extra work. *Engineering Project Work* on page J - 8 explained one way to build in a sense of organization using the **Context** and **Discussion** parts of the *Presentation Sandwich*. Another method is to add additional pages of work between major sections of work, pages that link the two sections together (i.e., a technical work transition paragraph). A third method is to refer to other pieces of work directly from within the technical work (e.g., "see results on page E-34"). Sections A and B of this workbook were added to the workbook to help accomplish the integration of all the work within the workbook.

The following material shows how to create a physical structure for your work, one that enhances the work's organization. It is assumed that all the technical work being organized has been prepared using the *Presentation Sandwich* (no amount of physical organization can produce a quality product if the technical work is poorly presented).

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Design Notebook and Portfolio Structure

Design Notebooks and Portfolios are two different names for the same thing; they are both organized collections of work. Typically you will find the term *Design Notebook* used in reference to a collection of work created by a team while the term *Portfolio* is used in reference to a collection of work created by an individual. Specifically:

A *design notebook* is an **organized collection** of team work, technical and *non-technical*, prepared for a particular project. It contains, in a purposeful sequence, all the work done for the tasks and sub tasks undertaken to complete the project. It contains Project Management information (agendas, minutes, etc.). It contains references to everything created as a result of working on the project.

and

A *portfolio* is an **organized collection** of individual work, technical and *non-technical*, prepared for a particular class. It contains, in a purposeful sequence, all your homework, assessment documents (e.g., quizzes, tests, evaluations of work, work logs, reflection logs, run charts), reports, projects, class notes (optional); i.e., everything created during the semester that relates to the class.

Portfolios and Design Notebooks (to be called Folders when referring to both) are organized collections of completed work that you can refer to later when you need to review what was done, how it was done, and what results were achieved.

Generally, these Folders are loose leaf, three ring binders, which permit the easy removal and/or insertion of material⁷, although the use of electronic based (e.g., Web based) folders is becoming more common. The particular number and order of the sections within the folder depends on the course and project and is neither mandatory nor unique. Figure 3 and Figure 4 show example structures for a Design Notebook and Portfolio respectively.

As is true for all your work, these folders are organized using the sandwich structure. Folders have front material, work, and end material. What generally goes into each of these sections is now discussed.

Front- Material

The front material of these Folders is the same, consisting of a Title Page and a complete Table of Contents. While the Title Page is static, the Table of Contents is dynamic, growing as more and more work is placed in the body of the Folder. These front material pages may or may not have page numbers and the Table of Contents would generally not be marked with a tab divider. If you are not sure how to format the Table of Contents see Table of Contents for this workbook.

⁷ In certain situations you may be asked to use a bound notebook that does not permit insertion of pages. This is especially true when patent and copyright issues are involved.

Part II - Physical Organization of Technical Work

Title Page

This is the first thing you see when you open the Folder. It should contain at least the team name (e.g., Team F4), the name of all the team members, the course name, the instructor's name, the semester, and an e-mail address for the team.

Table of Contents

This is the second page of the Design Notebook and is the index, organized by topic and date, to the work contained in the various tabbed sections. The major headings are the Tab names. The sub entries are the names of all the work products the team created while working on the projects. **Every** work product in the Design Notebook must appear in the Table of Contents with the starting page number for the work.

Labeled Tab Dividers

- I. Project Number 1 (replace with the actual name of project)
All work the team does on the first project goes in this section.
- II. Project Number 2 (replace with the actual name of the project)
All work the team does on the second project goes in this section.
- III. Project Management
All team meeting work goes in this section, including Team Norms (first page), meeting agendas, meeting minutes, and team process checks. This work will be assembled in chronological order. Work logs also go in this section.
- IV. Assessment
All team assessment checklists and the team exam go in this section. This section also includes any Run Charts that have been generated.
- V. Index
The Design Notebook Competency matrix goes here. This is an index to your work, organized by competency and level of learning.

Figure 3 - Design Notebook Structure for ECE 100

The Work

The work part of these Folders consists of the tabbed sections running from the Table of Contents up to but not including the Assessment Tab. It is in this middle part that all the work products are found.

number and names of tabs

The number and names of the tabs actually found in this section will vary with course and project. How many tabs you actually put in is a matter of choice. The tabs are present to make it easier to quickly get to the desired work product (criterion 1 for organized work). You probably do not want a tab for each work product, nor do you want only one tab for an entire semester's work. You will generally have tabs for what you consider to be the major divisions of effort. The number of tabbed sections shown

Part II - Physical Organization of Technical Work

Title Page

This is the first thing you see when you open the Folder. It should contain at least your name, the course name, the instructor's name, the semester and how you can be contacted (e.g., an e-mail address).

Table of Contents

This is the second page of the portfolio and is the index, organized by topic and date, to the work contained in the various tabbed sections. The major headings are the Tab names. The sub entries are the names of all the work products (homework, quizzes, reports, etc.) you have created while taking the class. Every work product in the Portfolio must appear in the Table of Contents with the starting page number for the work.

Labeled Tab Dividers

A. First Law

All assignments that concern primarily the First Law are filed in this section of the Portfolio.

B. Second Law

All assignments that concern primarily the Second Law are filed in this section of the Portfolio.

C. Cycles

All assignments that concern primarily cycles are filed in this section of the Portfolio.

D. Properties

All assignments that concern primarily properties are filed in this section of the Portfolio.

E. Class Notes

All of your class notes and course handouts are filed, chronologically, in this section.

F. Assessment

All quizzes, exams, work logs and run charts are filled in this section.

G. Index

The course Competency matrix is filed here. This is an index to your work, organized by competency and level of learning.

Figure 4 - Sample Portfolio Structure for Thermodynamics Class

in Figure 3 for the ECE 100 Design Notebook is small, one for each project and one for the project management work; however, this has been found to be satisfactory.⁸

While most Portfolios and all Design Notebooks use task (topic) titles for the tab labels (e.g., Homework, Chapter 1, First Law, Problem Definition, etc.), it is possible to use the Learning Outcomes of the class (see Section B for a discussion of Learning Outcomes).

⁸ You may add additional tabs for special bodies of work, e.g., for sketches and/or drawings, an assembly plan. Such tabs should be inserted in front of the end material tabs. Thus if a tab for drawings was added, it would become IV, with Assessment and Index changing to sections V and VI respectively.

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While there are some assessment advantages to this approach (see Part IV) it is generally more difficult to file work products in the Portfolio using this method; therefore, it is not recommended for your **initial** efforts.

page numbers

All work in the middle section must have unique page numbers. Page numbers are necessary if you want to refer to the work from another section. You also need the page numbers for the Table of Contents (and Index). You need page numbers to make navigation within the Folder easy (criterion 1 for organized work); it should be possible to open a Folder to any location and know whether you need to go forward or backward in the folder to get to a page of interest.

Having unique page numbers could mean that all pages are numbered sequentially throughout the notebook or a tabbed section of the notebook. While such a process does generate unique page numbers, such a process is a nightmare to accomplish. Luckily there are other ways to accomplish the same goal of unique page numbers.

The easiest way to generate unique page numbers is to use a multi-part page number like **X.Y.ZZ**. In this scheme **X** is the letter or number of the tabbed section the work is in, **Y** is the letter or number that designates the sub-task within the tabbed section, and **ZZ** is the page number of the sub-task work. Thus, if the notebook structure were that shown in Figure 3, the first work you did for Project 1 would have page numbers I.A.1 to I.A.5 (assuming there were five pages of work). The first page of work for the second sub-task would have the page number I.B.1. The first page of the first Project Management sub-task would have the page number III.A.1 (III for tabbed section III, A, for first sub-task, and 1 for the first page)⁹.

Occasionally you will need to insert new work into work products that you have already put into the Folder. You could renumber all the work or you could number the new pages to show that they fall between the two pieces of work already entered in the Folder. For example, if the work needs to go between pages II.B.45 and II.B.46, then you could assign page numbers II.B.45.1, II.B.45.2, II.B.45.3, etc. to the new work.

project management

Project management is a section in a design notebook that is not found in a portfolio. This tabbed section contains all the work associated with managing the project. As you can see in Figure 3 this includes all team meeting agendas and minutes, team and meeting process checks, team norms, and work logs. Typically this section would be subdivided into sub-sections, one sub-section for each of the various work products.

team meetings

Teams generally need to meet and discuss progress, make decisions, and work on some project task. Well run meetings can save the team much time and effort and the

⁹ It is sometimes permissible to drop the Tab Number from the page number. If this is done than all references to a page must include the name of tabbed section and then the page number. Such verbose referencing makes such a page numbering scheme hard to use with Competency Matrices that have very limited space for the page number.

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materials used to run the team meetings are found in this section. It is expected that there will be an agenda created for each meeting. If you have no idea about what an acceptable agenda might contain, review the Agenda Planner in Section K. The Planner is set up for one major task, if you have several important tasks you may want several Planners, one for each task.

In addition to the meeting agenda, the minutes from each meeting are expected to be found in this section. Minutes need to be more than a statement that each issue was addressed. The minutes must indicate the results of all important decisions (with some sense of the discussion leading up to the decisions). Generally the minutes will have action items, i.e., specific tasks that each team member has been assigned to accomplished by the next team meeting.

team and meeting process checks

Part of managing a project includes managing and improving the team. Any work related to this activity (e.g., development of team norms, the completing of team process checks, etc.) would be found in this section.

work Logs

Monitoring the amount of time spend on a project is important. Work logs, as the name implies, log the time spent preparing the work products you have created during the semester (i.e., the time spent on various class-related tasks). A sample work log template is shown in Appendix B (page J - 64). The log contains factual information related to your work. The log shows when the work was done, how much time was spent on the work, where the work was done, and finally a code that clarifies the type of work performed (more than one code entry is possible). If work logs are required you will need to update them at least once a week (several times a week is better).

End Material

The end material contains those items related to the learning associated with the material in the work section of the folder. All Portfolios have these sections; however, you will find such sections only in Design Notebooks associated with a course (i.e., it would be unusual to find this end material in a Design Notebook you created while working on a project in industry). All the work found in the end material must also have unique page numbers.

Assessment

A review of Figures 3 & 4 shows that the assessment section contains everything relating to assessing you and your work. The section contains your quizzes, tests, exams as well as all the assessment Checklists (see Part III) that have been used in assessing your work. The section has all of the written critiques of the work products. Depending on the class, this section may also contain Run Charts. As with the Project Management section, this section will have sub-sections for each major category of item (with a unique sub-section letter or number for the page numbering).

quizzes and exams

Any quizzes and/or exams (and their redos if required) that have been done during the semester will be found in this section. Any additional work associated with the quizzes and exams would also be found here.

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checklists

If your work is assessed using checklists (See Part III), the checklists will all be found in this section. The checklists should be organized according to general types of assessment. For example, all the team process check checklists would be together, all the exam checklists would be together, all the design work checklists would be together.

run charts

When a quantity varies significantly over time (e.g., the outdoor temperature, weekly time spent on class work), it is especially useful to present a current value of the quantity (e.g., current temperature, hours spent this week) as well as a time averaged value of the quantity (e.g., average temperature over the last six hours, average weekly hours spent over the semester). The name Run Chart is assigned to presentations of this time history of a quantity. One way to present such data is to enter the time varying values and their time averages into tables. However, trends are hard to see in tables; therefore, this data is generally also shown on a plot having time as the horizontal axis and the time varying value on the vertical axis. The plot must show the instantaneous as well as the time averaged values, generally shown as separate curves on the plot.

A sample Course Effort Run Chart is shown in Appendix B (page J - 65). Notice that both the plot and the table used to create the plot are shown. The plot has time along the horizontal axis (i.e., week number) and the Hours Doing ECE 100 Work along the vertical axes. The plot and table contain both the weekly value as well as the running average over the semester of the weekly value. You can see that in the first week the student spent 3 hours on the course and the running average was also 3. In the second week the student spent 8 hours and the running average had increased to 5.5 (i.e., $(3+8)\div 2$). Looking at the chart you can see that the maximum hours spent occurred during week 4 and that the running average at the end of the semester was 9.9 hrs/wk. This Run Chart shows the advantage of plotting the running average; the running average is smoother, fluctuating much less and can be used to make a prediction as to the expected amount of time that would be spent in Week 17 (i.e., about 10 hrs).

Index

The second part of the Back-End material is the Index. The Table of Contents is one type of index; however for assessment purposes, you need to have a second index at the back of your portfolio or design notebook. This index is the course Competency Matrix (see page J - 38) you received at the beginning of the semester. Place this matrix in your Folder and; as you add work, enter page numbers (indicating location of the work) in the matrix. You can consult Step 4 - Updating the Matrix on page J - 44 for a fuller discussion of how this index is maintained.

Part II - Physical Organization of Technical Work

Placing Material in the Portfolio or Design Notebook

Once you obtain your binder and add the tabs you have an empty Folder ready for your work products. When you complete each assignment you should place the resulting work product(s) in the Folder. The process for doing this is:

1. Determine where the work belongs; i.e., which tabbed section and sub-task within the section. If it seems that the work could go in several different sections or sub-tasks, select one of the possibilities. If there does not appear to be a logical section or sub-task (e.g., the work is from Chapter 3 but a Chapter 3 section does not exist, or the work is Problem Definition work for project 2 and that sub-task does not exist, etc.) then create a new section or sub-task. Do not forget to enter the new section or sub-task into your Table of Contents.
2. Once you have determined the appropriate location for the work, place the work in the folder and add the appropriate page numbers to the work. If the work is a continuation of an exiting sub-task, the page numbers will continue from the last page number of the sub-task. Thus, if the current Problem Definition sub-task ended at page I.A.26, more Problem Definition work would start at I.A.27.
3. Once you have added the appropriate page numbers to the work and inserted the work in the Folder, turn to the Table of Contents and add the name of the work to the appropriate section. Select a meaningful name for the work (e.g., "Duncker Diagram On Toothpaste, problem 2.5", etc.) and enter the work's first page number in the Table of Contents.
4. If you have covered the material in Part IV -- Assessment - Levels of Learning and understand something about the Competency Matrix, you can now update the matrix (i.e., add the page numbers of the new work to appropriate locations in the matrix). As you update the matrix you may be required to write an entry in a Reflection Log; your instructor will notify you if Reflection Logs are required.

What Now?

You now have an organized collection of technical work. But questions remain. Is the work satisfactory, i.e., does it meet expectations? Is the work complete? Is the work presented according to expectations? What level of understanding of the material is shown by the work (i.e., is the work indicative of a person just getting started or is the work reflective of an expert)? These are assessment questions that will be dealt with in the next two parts of this guide. First, meeting customer expectations and the use of Checklists is discussed; this is followed by a discussion of how to assess the educational state shown by your work product.

Part III – Assignment Expectations & Assessment Using Checklists

When you are instructed to complete a work product and turn it in to be “graded” (assessed) how do you know what to submit? When the instructor says he wants *neat* work does this mean one inch margins, laser printed, spell checked, ink drawings, hand printed, boxed answers, straight edges used for all lines, or does he just mean no coffee stains on the work product? How do you know when you have actually completed an assignment? How do you know what might be considered “extra” and what might be considered required by the grader? How do you know if you have prepared a quality work product or one that needs improvement?

It clearly behooves you to get answers to these questions. Interestingly, it also behooves the faculty, the customers of your work products, for you to get answers to these questions because the potential learning associated with an assignment is enhanced when you know what the faculty actually expects. This part of the guide addresses the use of checklists as the method used to express faculty expectations and assess your work products. You should review the assessment process discussed in Section B and Kano’s model of customer satisfaction covered in Section E before reading this material¹⁰.

Applying Kano’s Model to Assessment

The checklists that are discussed in this part of the guide have been developed to be consistent with Kano’s model of customer expectations. It turns out to be relatively easy to apply Kano’s model to the assessment of your work products. In Kano’s model the faculty are the customers of your work. The faculty’s reaction to your work products (i.e., how they grade your work product) is completely analogous to the way any customer reacts to a product, i.e., they are either excited, satisfied, or disappointed. Thus, all work is assessed as either Exceeds Expectations (exciting), Meets Expectations (sufficing), or Needs Improvement (disappointing).

Kano’s model helps to more fully define each of these outcomes. Specifically:

1. Exceeds Expectations (**E**): there is more and/or better work present than expected, i.e., all of the Expected Features¹¹ are present **plus** a satisfactory number and level of Revealed Features, **and** some Exciting Features are **also** present.
2. Meets Expectations (**M**): all expected items are included, i.e., all of the Expected Features are present **plus** an acceptable number and level of Revealed Features.
3. Needs Improvement (**NI**): an Expected Feature is missing from the work, **or** the number of Revealed Features or the level of Revealed Features is insufficient.

The question is: What exactly are these Expected and Revealed Features?

¹⁰ Much of the material for this section comes from a paper by McNeill, Bellamy, and Burrows that is to be published in the ASEE Journal of Engineering Education.

¹¹ The word *Requirement* has been replaced with *Feature* in our discussion of Kano’s model.

Part III – Assignment Expectations & Assessment Using Checklists

Creating Assessment Checklists

The answers to the previous question are contained in the checklists that are prepared for most of the work products you are asked to prepare. This section reviews a generic checklist and then looks at how the faculty create and then use the checklist during assessment. The insight into how the faculty create and use checklists should help you understand how to meet and/or exceed expectations as you create your work products.

Creating a Generic Checklist

The basic checklist has three parts, one for each type of Kano feature; an example checklist template is shown in Figure 5. This checklist shows that each of the three features is assessed differently. Expected Features are either present or absent in your work product; thus, a Yes / No assessment is appropriate. Similarly Exciting Features are either present or absent; however, unlike Expected Features, the absence of exciting features is **not** a negative issue and does not result in dissatisfaction; therefore, a Yes or blank assessment is appropriate for Exciting Features. Unlike the other two features, the Revealed Features have a degree or level to which they are present. Although it might be possible to assess this degree or level on a scale of 1 to 10, a coarser granularity is used. Revealed Features are assessed as Wow, Ok, or Weak.

The material at the bottom of Figure 5 shows how the assessment of the various features is converted into a final assessment for your work product. The figure shows that you can Exceed Expectations only if: (1) all Expected Features are met (i.e., no “No”s); (2) all the Revealed Features are met to at least an acceptable level (i.e., no “Weak”s); **plus** (3) there is some extraordinary achievement for some Revealed Features (i.e., some “Wow”s); **and/or** (4) there are some Exciting Features present. Further, your work is assessed as **NI**, *Needs Improvement*, when either some Expected Feature is not present, and/or too many of the Revealed Features are Weak. Finally, if too much of your work does not meet expectations (e.g., too many “No”s or “Weak”s) your work is assessed as **NCE**, *Not a Credible Effort*.

There are three other important features of this generic checklist that you should take note of. First, the checklist is designed to be used by more than one assessor on different dates (e.g., self, peer, grader, faculty). The date of each assessment is recorded; each assessor uses a different symbol that clearly identifies them. Symbols rather than colors are used so the checklists can be photocopied without losing the identity of the various assessors. Second, there is space for comments about any No’s. You can expect to read some comment about any No you receive (e.g., how the No might be corrected or improved). Third, the fourth column for the Revealed Features (and second column for the Exciting Features) is used for comments (the boxes are generally at least an inch high). Comments justifying the assessment are **required** for any Wow, Weak, or Exciting Feature but may be omitted if the assessment is Ok.

Part III – Assignment Expectations & Assessment Using Checklists

Name: _____ Work Products Being Evaluated: _____

1. Work Evaluated by _____ Assessment Symbol _____ Date _____

2. Work Evaluated by _____ Assessment Symbol _____ Date _____

Yes	No	Expected Features	
		1.	
		2.	
		3.	
Comments on any No's			
Wow	Ok	Weak	Revealed Features
			A.
			B.
Yes	Exciting Features		

Results of Assessment

E	M	NI	NCE NS	Informative Memo
				1. E , Exceeds Expectations, requires all Yes's for the <i>Expected Features plus</i> at least several <u>Wow's</u> (no Weak's) and/or perhaps some <i>Exciting Features</i>
				2. M , Meets Expectations, requires all Yes's for the <i>Expected Features plus</i> at most a few <u>Weak's</u>
				3. NI , Needs Improvement, is assigned if there are any No's for the <i>Expected Features</i> or if there are too many <u>Weak's</u>
				4. NCE , No Credible Effort, mostly <u>No's</u> and/or <u>Weak's</u>
				5. NS , no work submitted

Figure 5 - Generic Checklist for the Assessment of Work Products

Part III – Assignment Expectations & Assessment Using Checklists

Creating and Assessing the List of Expected Features

The first step in creating a checklist is the generation of the Expected Features. Expected Features are generally not spoken; they are assumed to be known by both you and your customer (i.e., the faculty). However, because of the differences between the faculty's and your points of view about what is "expected" on an assignment, it has turned out to be important to "speak" these Expected Features.

Expected features come primarily from three sources: a) specific instructions given in the assignment, b) technical correctness of the work, or c) assumed prerequisite knowledge and/or skills. The faculty consider the following as they develop their list of Expected Features for an assignment.

1. Most assignments have very specific requirements about work product presentation and organization (see Part I). These requirements constitute a set of specifications that must be achieved for the work to be accepted. For example, all your work is required to have a *sandwich* structure (see page J - 1). Items in this category are often connected only peripherally to the course and assignment learning objectives.
2. Assignments will also normally have at least one technical issue that is assessed to determine whether you have mastered a relevant technical course content item. Mastery of these technical issues is a primary learning objective associated with each assignment. These technical issues reflect the "unspoken" statement that the work must be done correctly. For example, it would be expected that all work for a thermodynamics class would satisfy the First Law.
3. The last category of items in the set of Expected Features are those associated with what the faculty assumes you have already mastered prior to the assignment, either from prerequisite courses or from material presented and mastered earlier in the course. When prerequisites are included in the Expected Features, you know what the faculty assumes about your preparation. For example, in a mechanics course, faculty could reasonably assume that you have mastered enough physics to correctly model relevant forces.
4. Since the checklists are distributed with the assignment, the faculty recognizes the importance of having an essentially complete list of Expected Features. The assessment process does **not** allow the addition of Expected Features **after** the assignment has been completed and submitted. However, and this is a very important *however*, you should realize that there are some "unspoken" Expected Features that are so fundamental and obvious that they are left "unspoken", i.e., not listed as Expected Features in the checklist. For example, few faculty in a U.S. engineering program would consider it necessary to specify that assignments must be written in the English language. It does occasionally happen that a work product will be assessed as Needs Improvement because it is missing or has not satisfied one of these "fundamental" or "obvious" requirements.

Once you know what the Expected Features are, the Expected Features are the easiest of the features to assess. They are either present (Yes) or they are absent (No). Every attempt is made to write the Expected Features with no room for interpretation.

Qualitative issues related to the work product, which are open to interpretation, are assessed in the Revealed or Exciting Features.

Part III – Assignment Expectations & Assessment Using Checklists

Creating and Assessing the List of Revealed Features

The second step in creating checklists is the identification of Revealed Features. Unlike Expected Features, Revealed Features are “spoken”. When you ask a faculty member “what they want on an assignment” their response is almost always some aspect of a Revealed Feature.

Revealed Features primarily address three issues: 1) the level of effort invested in the work, 2) the demonstration of mastery of course concepts or skills, particularly those concepts and skills that are developed continuously throughout the semester and 3) the quality of the work product. The question you must answer for each of these issues is: What constitutes an Ok and/or Wow effort.

Assessing the set of Revealed Features is somewhat more subjective than assessing Expected Requirements. As you read the following material notice that while each of these issues are assessed a bit differently, getting a Wow requires a good discussion to be part of the work. The examples given in the following material are examples of ‘pushing the envelope’ of the course/assignment learning objectives, and are generally achieved through extra effort. They may, but do not necessarily, require creativity on your part.

assessing level of effort

In a typical homework assignment, there is some assumed level of effort required for each problem (e.g., represented by the solution published in the solution manual for the textbook). If your work product were comparable to this *published solution*, your work product would be assigned an Ok. If your work product were missing significant parts of this *published solution*, even if you managed to get the “correct” answer for the problem, your work product would be assigned a Weak for a *level of effort* Revealed Feature.

To get a Wow your work product must go beyond what would be found in the *published solution*. The *going beyond* must be both consistent and relevant with the initial problem assignment, showing a deeper understanding of the problem. Running three cases when one was all that was expected does not automatically constitute *going beyond* what was expected. Running three cases and discussing how each case increased your understanding would be a candidate for a Wow.

assessing mastery of the material

Every assignment you do is an opportunity to demonstrate to the faculty your mastery of course skills. When your work shows mastery at the level expected for the assignment, the work will be assessed as Ok. There are several things you can attempt if you want your work product assessed as Wow. Two of the more common ways are to:

- demonstrate a level of learning (mastery) beyond that desired in the original assignment (for example, demonstrating analysis-level work when application level was all that was assigned);
- generate an insightful reflection on the role of the assignment in achieving the learning objectives of the course, or on the role of the assignment in your own learning.

Part III – Assignment Expectations & Assessment Using Checklists

The expected mastery level for an assignment may be explicitly given with the assignment or you may have to deduce the level based on the type of assignment (see Maximizing Your Opportunities on page J - 46 for more thoughts along these lines).

assessing quality of work product

Of the three Revealed Feature issues, quality is by far the most subjective. As with the level of effort, if your work “looks” like the *published solution* your work product would be assigned an Ok for quality. If your work products are “noisy” (i.e., messy, hard to follow or understand) they will be assigned a Weak for *quality*. If your work product were more complete, more fully annotated, better organized than the *published solution* your work would be a candidate for a Wow.

You need to be careful that your quality efforts are consistent with the problem and add something useful or meaningful. Just as running three cases when one was requested does not automatically lead to a Wow neither does using a color printer to produce multi-colored work products automatically lead to a Wow for *quality*. The color must add something useful to the work product. For example, if the color is used to show categories of variables and there is a discussion of the how the various categories of variables impacted on the solution method, then it is possible that the color is adding appropriate (unexpected) quality to the work product and the work product would be a candidate for a Wow.

The quality issue may overlap other areas. It is not uncommon to have Wow quality present in work products that also demonstrate a better mastery of the material than was expected. Quality may also be assessed as an Exciting Feature.

Recognizing Exciting Features

Exciting Features are the most subjective. Exciting Features are only recognized when seen. Since specific Exciting Features cannot be defined in advance of the work product being created and submitted, only a blank box for comments is provided on the checklist. What sorts of things are the faculty looking for when they assess your work product has having an Exciting Feature? Some possible approaches that you might consider are:

- recognizing and answering relevant questions beyond what was originally asked;
- obtaining and discussing in context some relevant information from a source outside the assigned sources;
- comparing and contrasting results generated in an assignment with other assignments/ courses/topics in a way that provides a broader understanding than was originally specified;
- invention (and reasonable development) of alternative approaches to achieve the same technological or learning objective specified in the assignment.

Does this sound like what was suggested for Revealed Features? Kano’s model is helpful in resolving the apparent overlap between extraordinary achievement of Revealed Features, and achievement of Exciting Features. Revealed Features are normally associated with explicit course/assignment learning objectives; they are “spoken”. Exciting features, which are “unspoken”, normally result from unusual

Part III – Assignment Expectations & Assessment Using Checklists

creativity, are not necessarily directly related to the course or assignment learning objectives, and do not necessarily require extraordinary effort.

Using Checklists

Although checklists were created to help the faculty with the final assessment of your work products, you can use checklists to enhance your chances of creating quality work products. But to take advantage of the checklists you cannot operate in your old mode (i.e., you cannot just do the work, turn it in, and wait to see how well you did). To get the most out of the checklists you need to:

- plan your work before you start,
- do the work, i.e., create the work product, and
- self assess (and, if permitted, peer assess) the work product.

The first and last bullet are the new steps and are pedagogically very important in helping you better understand and accomplish the learning objectives associated with each assignment.

Plan Before the Work Is Started

You must think about the assignment before you start. Since you have the checklist before you start your work, you have the list of features that must be present (Expected Features) and the list of features that will be considered for Exceeding Expectations (Revealed Features). Use the checklist to set priorities and make decisions. First decide what to do to satisfy all Expected Features. You must then decide what effort will lead to an acceptable achievement of the Revealed Features. Finally, you can then consider whether you want to attempt extraordinary achievement of Revealed Features, or want to attempt achievement of Exciting Features. It is possible that you do not have the time to attempt an Exceeds work product and will simply concentrate on Meeting Expectations. These decisions are best made before any significant work is actually begun.

Do the Work

Once you have decided what needs to be done you can create the work products. As you complete the work product be sure to keep the Expected and Revealed Features in mind. Review your plan to make sure you have done everything you intended to do.

Assess After the Work Is Completed

The last step is the self assessment of the work product prior to submission. Of the three steps, experience has shown that you will probably find this self assessment step the most difficult step to do well. You should always complete the checklist before submitting the work. This assessment need be nothing more than a final review of your work to make sure its quality Meets or Exceeds Expectations.

You should be especially careful when you check each Expected Feature; make sure the feature is actually present. Observation has shown that you tend to assess Expected Features somewhat cavalierly, often marking items as present that are in fact *not* present. One technique you might try to help overcome this problem is, as you check for each Expected Feature, write down the page, on the checklist, where the

Part III – Assignment Expectations & Assessment Using Checklists

feature is located in the work product.

As you move on to the Revealed and Exciting Features, if you self assess the work as Wow or having Exciting Features, you **must** supply the reasons for this assessment on the checklist. It is never enough to just mark an item as Wow and not give the reasons. While the faculty may not agree with your assessment, if you do not give the faculty your point of view about the work, the faculty will never know what you were thinking. It has happened that work products that would have been assessed as Ok get assessed as Wow as a result of your comments.

Reviewing Two Commonly Used Checklist

Before leaving this material on checklists it is useful to look at two actual checklists. Two of the very frequently used checklists are shown in Figure 6 and Figure 7. The checklist shown in Figure 6 is used for **all** work while that shown in Figure 7 is used only when plots or charts are included in the work. As you can see from the text at the top of the checklists, these checklists are not necessarily turned in with each assignment but you are expected to have developed work products that would achieve a Meets on these checklists.

The two checklists shown in Figures 6 & 7 are the mapping of the text material you read in Part I of this guide into a specific checklist. In Figure 6, the first and list item concern the existence of the front and back material (J - 1). The expectation that all work is signed (J - 4) shows up at item 2 in Figure 6. The material on graphic materials standing-along (J - 9) is covered by items 1 to 4 in Plot Checklist, Figure 7.

You probably noticed that both of these checklists are a bit different than the generic checklist shown in Figure 5. For one thing, neither checklist has an Exceeds column; the best you can earn on either checklist is a Meets. These two checklists are really sub-checklists that address very specific Expected Features of the work product. These features are either present (i.e., a Meets on the sub-checklist) or they are not (an NI or NCE on the sub-checklist). Use of sub-checklists enables the main checklists to be more compact (e.g., instead of having all the items shown in Figure 6 appear on all checklists it is possible to have a single Expected Feature that says "The work product satisfies the Presentation of Technical Work Checklist").

Another difference between the checklists shown in Figure 7 and Figure 5 is that for plots, a single Weak will give you a Needs Improvement (in general it is possible to have several Weak's and still get a Meets). The lesson is that it is important to always look at the assessment box to see what the standards are for Meeting expectations.

Part III – Assignment Expectations & Assessment Using Checklists

Evaluation of ___'s Work Evaluated by: ____

Work Product Being Evaluated _____

The following Checklist can be used to assess any body of technical work to make sure the work is being presented according to the expectations of the ECE 100 faculty. This Checklist is referred to in all the other Assessment Checklists that you will be using and, while you may not actually print and fill in this Checklist for all of your work, you will need to at least mentally complete this Checklist for **all** of your work.

Yes	No	Expected Features
		1. There is material (i.e., a Context) at the start of the work which marks the beginning of the new work and orients the reader (i.e., gives the reader some sense of what follows)? This material could: <ul style="list-style-type: none"> a) <u>explain why</u> the work <u>will be/was</u> done (e.g., This is a homework assignment on equilibrium or This work on frame weight will be undertaken to get a better idea about how much this Home Exercise Machine might weigh; I prepared this memo on our power shortages after last Friday's power outage at Unit 67), or b) <u>tells</u> the reader <u>what</u> will be accomplished when the work is done (e.g., After this assignment is completed I will have shown I know how to do force balances and will be prepared for the quiz or When this work is completed we will know the frame weight), or c) <u>tells</u> the reader <u>how</u> this work fits into a bigger problem (e.g., This is the third assignment from Chapter 3 or Estimating the cost of the Home Exercise Machine requires knowing the weight of the machine's frame which is determined in the following work), or d) <u>tells</u> the reader the important topics to follow and the order the topics are addressed (e.g., This report first discusses the methodology used, then presents the test results, and ends with a discussion of the testing)
		2. There are dates and names of the people who did the work on at least the first page of the work
		3. The work has a professional appearance (e.g., the material is readable, neat, plenty of white space, figures have descriptive titles, plots have acceptable annotation)
		4. Based on the Context, the work is what you expected to see
		5. The work is professional and ethical
		6. There is material (i.e., Discussion) at the end of the work which marks the end of the work and discusses or reflects on the work done. This end material could discuss: <ul style="list-style-type: none"> a) <u>what was learned</u> (e.g., The frame weight was 34 kilograms which is much lighter than any machine we have found in the stores or This cone surface area of 250 m² is huge, about a third of a football field), or b) <u>the process used</u> in working the problem (e.g., I could not work this problem until I realized I could replace 1 with $\sin^2\theta + \cos^2\theta$ or Until we simplified the frame, we were not able to get our model to converge), or c) the <u>correctness</u> of the result (e.g., The answer to this problem is 14.6 m², which matches the answer in the back of the book or This weight of 34 kilos, while it seems light, is probably correct; the model was checked using example problem 4.5 in Shigley), or d) <u>what will happen next</u> (e.g., Now we can calculate the cost of our device)

Results of Assessment

M	NI	NCE	Presentation of Technical Work <ol style="list-style-type: none"> 1. M, Meets Expectations, requires all <u>Yes</u>'s for items 1 to 6 2. NI, Needs Improvement, is assigned if there are any <u>No</u>'s for items 1 to 6 3. NCE, No Credible Effort, is assigned if there is little to no work to be assessed
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Figure 6 - Checklist for Assessment for Presentation of Technical Work

Part III – Assignment Expectations & Assessment Using Checklists

Evaluation of _____'s Work Evaluated by: _____

Plot or Chart Being Evaluated _____

The following Checklist can be used to assess any plot or char to make sure the work is being presented according to the expectations of the ECE 100 faculty. This Checklist is referred to in other Assessment Checklists that you will be using and, while you may not actually print and fill in this Checklist for all of your work, you will need to at least mentally complete this Checklist for **all** the plots your create.

Yes	No	Expected Features
		General Graphics Issues
		1. The graphic has a complete descriptive title
		2. All variables shown on the graphic are defined
		3. The graphic would still make sense after copying
		4. The copied graphic makes sense when shown to someone who should understand it (i.e., the graphic can stand alone)
		General Plot Issues
		5. Both axes have descriptive titles (N.B. not a single letter) which include units
		6. The axes have labeled divisions (text or numbers)
		7. The “ values ” for both axes at the origin of the chart are defined and unambiguous
		8. The dependent variable (item measured or predicted) is plotted on the vertical axis
		9. If the variables are presented in the chart’s title , the dependent variable is mentioned first
		10. There is a legend if there is more than one chart or plot line
		11. The data points are shown if the data is experimental or measured
Comments on No's		
Ok	Weak	Revealed Features
		Rate the quality of the plot

Results of Assessment

M	NI	NCE	Plot
			1. M , meets expectations, requires all Yes's and No Weak's
			2. NI , needs improvement, is given if there are any No's or Weak's
			3. NCE , no credible effort, is given if there are more than six No's plus Weak's

Figure 7 - Checklist for Assessment of Plots

Part IV -- Assessment - Levels of Learning

There are a number of ways to assess technical work. Is the work technically correct (although technical correctness is always necessary it is not addressed in this material); is it well presented (see Part I); is the body of work (i.e., the collection of work in a Portfolio or Design Notebook) well organized (see Part II); does the work meet customer expectations (see Part III), is the work indicative of that done by a novice or an expert? It is this final question that is discussed in this section.

Assessing what you know and how well you know it is an important part of any educational process. Generally a course instructor has done this assessment after reviewing the work you submit. However, as you become a self-regulated learner (see Section B of this Workbook), you will need to assume more and more of this assessment task; therefore, you need to understand how this assessment is performed. Before discussing this process, it is important that you learn how *experts* in assessment define the stages of knowledge; it is also necessary to learn about the course Competency Matrix, a tool used in the assessment process.

Educational States

The Random House College Dictionary defines education as:

the act or process of imparting or acquiring general knowledge and of developing the powers of reasoning and judgment

This definition shows education to be an active, dynamic process, changing your general knowledge and/or ability to reason and use judgment. It follows that learning is associated with the actual *acquiring* and *developing* aspects of this definition. When you *learn* a history lesson you are obtaining knowledge about the activities that occurred during some period of time. When you *learn* to drive a car you gather knowledge about the car, the rules of the road, and develop a sense of when it is and is not safe to pass, a reasoning/judgment activity. *Learning* is the method or way by which you acquire and develop knowledge and wisdom. There is no single, correct, way to learn something; different people learn in different ways.

By definition, education is a process. That means something is changing; but, **what** is changing and how do you **measure** this changing quantity? Your skills, knowledge, reasoning powers, attitudes, and behaviors are changing. This collection of attributes is covered by the umbrella concept of an Educational State. Thus, the alternative definition of education becomes:

Education is the process that changes a person's educational state

Traditionally the evaluation of the status of your educational state has been done by a course instructor who assigned a grade to indicate your **state**. While it may be relatively easy to let instructors evaluate your work (i.e., you do the assigned work, submit the work, and wait to see what the instructor reports), in the long term **you** must be able to perform the evaluation. You cannot continually rely on someone else to tell you how you are doing; you must learn how to evaluate your own educational state in order to improve.

Part IV - Assessment - Levels of Learning

How can educational states be defined or characterized? One way is to characterize your educational state based on your activities and actions (i.e., behaviors) as well as those of your instructor. Reflect back over your years in school; you should be able to recognize the major changes that have taken place in your activities. During the first several years you learned facts and worked **simple, single concept** problems; during later years you worked problems that combined many different concepts and skills.

In the early 1950's a group of educational psychologists addressed the problem of defining educational states. To quote from the Foreword to their first effort:

It (this work) is intended to provide for classification of the goals of our educational system. It is expected to be of general help to all teachers, administrators, professional specialists, and research workers who deal with curricular and evaluation problems. It is especially intended to help them discuss these problems with greater precision.¹²

These psychologists divided the problem into three behavioral domains: the **cognitive**, dealing with the *recall or recognition of knowledge and the development of intellectual abilities and skills*; the **affective**, dealing with *interests, attitudes, appreciations, values, and emotional sets or biases*; and, the **psychomotor**, dealing with the *manipulative or motor-skill area*. These psychologists attempted to define a finite set of recognizably distinct behaviors and then sequence these behaviors in the order they occur when someone is learning (i.e., they were striving to define a taxonomy¹³ of cognitive, affective, and psychomotor behaviors associated with learning).

Cognitive Domain

A taxonomy¹⁴ that dealt with the cognitive domain, was published in the mid 1950's. After considerable discussion and testing of ideas with a wide range of colleagues, Bloom et al. proposed a cognitive taxonomy containing six major categories. In order of increasing complexity (and learning) they were: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Each of these categories was characterized by a different set of abilities (behaviors) exhibited by a person functioning in the category. This taxonomy is widely accepted and is the basis for many curriculum development efforts.

In the late 1980's and early 1990's David Langford, while implementing an important aspect of the quality culture (empowerment) in the classroom, recognized that the cognitive taxonomy could be used by the students, as well as the teachers, to determine their educational state. Langford proposed having the students use these educational objectives to do self evaluation. Langford renamed the objectives Levels of Learning, changed the name Comprehension to Know - How, and developed summaries of the

¹² *Taxonomy of Educational Objectives Book 1 Cognitive Domain*, Bloom et al., Longman, 1956.

¹³ The systematic distinguishing, ordering and naming of type groups within a subject field, *Webster's Third New International Dictionary*.

¹⁴ *Taxonomy of Educational Objectives Book 1 Cognitive Domain*, Bloom et al., Longman, 1956.

Part IV - Assessment - Levels of Learning

types of activities a student and teacher would undertake when the students were functioning at these various Levels of Learning¹⁵.

A modification of Langford's material on typical activities can be found in the first six pages of Appendix A. This material consists of answers to a set of seven standard questions. The answers to the questions change as the Level of Learning changes. For example, at the Knowledge Level the question *How do I know I have reached this level?* is answered, *I recall information*; at the Synthesis Level the same question is answered, *I have the ability to put together parts and elements into a unified organization or whole that requires original, creative thinking*. You should carefully read the answers to these questions in Appendix A, paying particularly close attention to the first two and last three questions for each of the levels.

Affective Domain

As the psychologists pointed out in the 1950's, there is more to defining an educational state than is covered by cognitive behaviors (Levels of Learning); the affective behaviors must also be considered. These affective behaviors cover a wide variety of issues ranging from the willingness to receive and try new material, or the interest in what is being learned, to valuing what is being learned or how the material is being learned. Aside from these issues, the affective domain also involves the related issue of Character (honesty, integrity, truthfulness, etc.). Myron Tribus, in several of his recent essays¹⁶, states that Character is one of the major categories of attributes that should be developed in a school or university.

What are the affective stages you pass through during the learning process? In the mid 1960's a subset of the group of educational psychologists who had produced the cognitive taxonomy published a second taxonomy¹⁷, one that dealt with the affective domain. Compared to cognitive behavior, affective behavior is a much 'softer' (i.e., harder to define) type of behavior with the result that the development of the affective taxonomy was a rather difficult task. It was hard to define exact categories of behavior that had definable boundaries; the categories seemed fuzzy and blurred rather than crisp and focused, as was the case for the cognitive categories. Eventually Krathwohl et al. defined five major categories that, in order of increasing complexity (called Degrees of Internalization) were: Receiving, Responding, Valuing, Organization, and Characterization by a Value or Value Complex. Each of these categories was characterized by the set of behaviors exhibited by a person operating in the category. Because the affective domain is rather fuzzy, the affective taxonomy has never enjoyed the wide spread acceptance given to the cognitive taxonomy.

The last pages of the material in Appendix A address the affective domain. You will find general material for the first three Degrees of Internalization. Only the first three Degrees of Internalization are discussed since the final two degrees are not considered

¹⁵ *Total Quality Learning Handbook*, Langford Quality Education, 1992.

¹⁶ *Quality Management in Education*, and *Total Quality Management in Schools of Business and of Engineering*, Myron Tribus, Exergy, Inc., Hayward, CA

¹⁷ *Taxonomy of Educational Objectives Book 2 Affective Domain*, David Krathwohl et al., Longman, 1964.

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by the authors to be appropriate for use in the university classroom. These top two degrees involve integrating an appreciation (valuing) of learning, as well as an appreciation (valuing) of the material learned, into your personal value structure, a structure that encompasses much more than educational values; thus, movement to these higher degrees of affective behavior must take place outside the classroom, in the broader context of your life.

Psychomotor Domain

Your psychomotor skills and abilities define the last piece of the educational state. As of this writing there has been no definitive taxonomy developed for these attributes; therefore, you will not be expected to evaluate this part of your educational state.

Competency Matrices

Course competency matrices can be an important part of every class you take. They can be used to define course goals; you can use the matrix to monitor your progress in achieving these goals. The level of detail in these matrices varies from class to class: some classes have only a vague outline, others have a more detailed matrix. In this course, these matrices are a fundamental component of the assessment process; therefore, it is important that you understand how they are created and how you might use them.

Defining A Course

In any class the instructor has a set of skills and knowledge (e.g., Engineering Design Process, Second Order Differential Equations, First Law of Thermodynamics, Teaming, etc.) that the class is expected to learn. This set of skills and knowledge are known as the *learning outcomes* for the class. Learning outcomes are generally rather abstract and must be characterized by (i.e., defined in terms of) a number of specific topics called *competency categories*. Depending on how specific the competency categories are, it may be possible (desirable) to further divide these competency categories into *competencies*.¹⁸

However, it is not enough to define the learning outcomes, competency categories, and competencies; the instructor must also decide, for **each** of these items, what cognitive and affective behavior levels the students should achieve. This collection of concepts to be learned and the levels to which they are to be learned can be organized and presented in a table known as the Course Competency Matrix. A simple matrix is shown in Appendix B; a more complete matrix is shown in Figure 2 of Section B in this Workbook.

The general design of the matrix is simple. Along the left side of the matrix are the general course Learning Outcomes (e.g., “differentiation” in Appendix B) along with the more specific Competency Categories (e.g., “implicit” and “polynomials”) and Competencies if they exist (Figure 2 of Section B shows this third level). Along the top of the matrix are the various affective and cognitive behavior levels and degrees. Each

¹⁸ You can read about how this process of transforming goals to subject topics was accomplished for the ECE 100 class in Section B of this Workbook.

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cell in the matrix represents the intersection of a particular competency, competency category, or learning outcome and a particular cognitive level or affective degree. For example, in the sample matrix in Appendix B there are two cells in the matrix for Analysis Level of Learning, one for differentiation, and one for team meetings.

Note the following in the sample matrix: first, the higher Levels and Degrees only apply to the broad collection of competency categories, i.e., to the learning outcomes. Also note that the Competency Matrix includes black dots, gray areas, and white areas. The black dots show the cognitive and affective behaviors you are **assumed** to have reached **before** you started the class. The white areas are the cognitive and affective performances that you are expected to achieve during the semester. The gray areas represent the cognitive and affective performance you **may** achieve, but are **not expected** to achieve. Finally, the numbers in the white boxes indicate where or when in the course the competency will be covered. In the example the numbers refer to a specific week in the semester (e.g., 2 means the material will be covered during week 2).

Monitoring Progress

At the beginning of a course, the matrix you receive will look like the one shown in the Appendix. It will show the **expected** changes in your educational state; however, it will **not** show your **actual** or **final** educational changes; you will add this information during the semester as you work the various assigned problems. Successful completion of all of these problems will enable you to demonstrate your achievement of the course goals. As you work these problems and are able to determine why they were assigned (i.e., what course goals are addressed by these problems), you can begin to monitor (i.e., keep track of) your progress in achieving the course goals by annotating the matrix. If you keep your annotation current, you can tell what you have learned to date by simply looking at the matrix (all boxes with page numbers show course goals achieved, all empty white boxes show goals yet to be learned and demonstrated).

The type of annotation you use will vary from class to class; in this class the matrix will be annotated using the page numbers of the work products in your portfolio or design notebook. When page numbers are used, this annotated matrix becomes an index to your work products, an index based on course learning goals.

Now that you have an understanding of educational states and competency matrices, you are ready to learn how technical work is assessed.

A Work Product Based Assessment Process

Knowing when you can fill in a box in the matrix involves assessment and takes some practice and a great deal of patience. Self assessment requires that you be able to answer the following two questions:

1. *How do I know when I have reached a particular educational state? and*
2. *What do I have to do to show myself, or someone else, that I have indeed reached this educational state?*

When you become an expert at self evaluation you can, and will, fairly and correctly evaluate your actual educational state with little more than internal (i.e., in your mind)

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evidence. But this type of *psychic* evidence will not be acceptable for classes or other situations where you must show others that you have reached a claimed educational state. In these situations you must supply **documentation** (information presented in some appropriate form) that **demonstrates** (shows) to the reader (evaluator) that you have actually reached the educational states you are claiming. Even in those situations where you are doing only self evaluation, the preparation and presentation of this documentation generally leads to a fuller understanding of the material (see General Presentation Expectations for Work Products in Part I).

While the ultimate goal is to be able to perform self assessment, practicing on your own work is a difficult way to learn the process; therefore, this material addresses learning how to assess someone else's work. Once you can assess a colleague's work you can start applying your assessment skills to your own work.

Assume you have been given a team design notebook along with the Course Competency Matrix and have been asked to assess the team's work. When you review the notebook you find the work is well organized and each piece of work is well presented. A review of the technical work shows it to be error free. The only thing that remains is for you to decide what level of learning and which Learning Outcomes or Competency Categories apply to this work (i.e., what boxes in the Course Competency Matrix apply to the work).

The general assessment process consists of the following four steps:

1. select a set of behavioral exemplars¹⁹ defined using a previously identified hierarchy of learning,
2. compare the work (the evidence) to this set of behavioral exemplars and select the exemplar that best matches the work,
3. explain in writing why the exemplar was selected (optional),
4. determine the relevant competencies and fill in the appropriate white boxes in the Course Competency Matrix.

How to perform these steps is discussed in the following material.

Step 1 - Selecting Behavioral Exemplars

You are to use exemplars based on the various Levels of Learning and Degrees of Internalization defined by the two educational objectives taxonomies introduced earlier. You are to use the material found in Appendix A as the *definitions* of these behavior states.

Step 2 - Matching Work to An Exemplar

Selecting the appropriate exemplar involves reading the various definitions and descriptions of activities associated with each exemplar and then comparing these activities with the activities that have been explicitly presented in the work. This is not an easy task. The following two examples may give you some insight into this process.

¹⁹ Exemplar - that which serves as a pattern, especially an ideal pattern; see Appendix A for the cognitive and affective exemplars used herein.

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Simple Mechanics Example

Consider the simple mechanics problem on page J - 67 of Appendix C; assume that you are assessing a work product representing a solution to this problem. What **Level of Learning** is demonstrated by the first solution on J - 68?

Start at the lowest level, **Knowledge**; locate the exemplar for **Knowledge** in Appendix A. Next, locate the section '**What are typical ways I can demonstrate my knowledge?**' This section includes examples such as: *"Define technical terms ..."*, *"List the characteristic methods ..."*, *"Describe the general problem solving ..."* Also locate the section **"What are typical work products?"** This section includes examples such as *"3. Modifications of example problems ..."* These examples appear to match this work product; e.g., the student clearly states that the problem is similar to an example problem in the textbook and it appears that he may have merely changed the numerical values in the example. However, before selecting this exemplar, you should consider the **Comprehension** exemplar.

The exemplar for **Comprehension** includes examples such as: *"Read textbook problems ... solve the problems."*, *"Draw conclusions based on the solution ..."* and a typical work product is described as *"Solutions to textbook problems ..."* This also appears to be a reasonable description of the work product; however, *"a summary of the learning objectives ..."* [see 2.(a) in the exemplar] is **not included** in the work product **nor** is the *"... general solution method ... used ..."* immediately evident [see 2.(c) in the exemplar]. The work product clearly states that the problem is similar to one in the textbook; thus, you might infer that the general solution method is included in the textbook.

In summary, the work product is either Knowledge or Comprehension level of learning. Since 2.(a) is not present and 2.(c) is not immediately evident, we believe that the **Knowledge** exemplar more nearly represents the Level of Learning for this work product. Also see the heuristic on page J - 43 for assigning a level of learning when the work product partially matches two or more exemplars.

N.B. In general, before selecting the **Comprehension** exemplar, you should always consider **both** the **Application** and **Analysis** exemplars; recall that **Analysis** level does **not** require **Application** level; thus, Application and Analysis are comparable Levels of Learning.

Furthermore, it is the **presentation** of the solution that distinguishes between Comprehension, Application, Analysis, Synthesis, and Evaluation level work products; i.e., the **content**, **amount**, and **depth** of the **presentation**. For example, the student who submitted the first solution assessed above **may** have been at Comprehension level; however, the **presentation** of the solution **did not demonstrate** Comprehension level. Review the '*presentation sandwich*' on page J - **Error! Bookmark not defined.** for a detailed discussion of the presentation of technical work.

What **Degree of Internalization** is demonstrated by the first solution on J - 68? The process described above can also be used to determine the Degree of Internalization. Start at the lowest degree, **Receiving**. Appendix A illustrates that **Receiving** includes

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activities such as “... *listen* ..”, “... *read* ...”, “*prepare notes* ...”, etc. These passive activities do **not** describe this work product. The next degree, **Responding**, includes activities such as “*I learn by doing*.”, “*I answer questions in class* ...”, “... *solve homework problems*.” Two of these examples appear to match this work product; i.e., there is at least a partial match between what the student has done and the list of possible activities (i.e., “... *solve homework problems*.”) Finally, review **Valuing**; this degree includes activities such as “... *solve problems using the knowledge ... that I have learned*.” “... *solve problems* ...”, “... *can justify or explain this belief* ...”, and “*am concerned when people express skepticism about the material* ...” This exemplar is possible; however, there is no evidence of this attitude included in the work product; thus, we concluded that this student has achieved **Responding** as an Affective behavior. Note: it would be **unusual** to find students reaching **Valuing** in an introductory class.

Review the other two solutions to this problem (pages J - 69 and J - 70). What Level of Learning and Degree of Internalization are demonstrated by those two work products?

A Higher Level of Learning Example

Consider the following: suppose you have created a report that explains the process you used in designing a bridge that had been assigned as a team design project. What cognitive level for the *failure analysis* might this report and the accompanying technical work support? A review of the lower cognitive levels shows partial matches for Comprehension and Application with Application seeming to be the best choice since you were not told exactly how to design the bridge and had to recognize the utility of the solution methods you used.

The Analysis exemplar includes activities such as: “*breaking ideas [etc.] ... into component parts*”, “*[able to] explain ... why the whole does or does not work*”, “*[able to explain] causal relationships between the parts*”, and the typical work product is described as “*extensive discussion of the work*”. Your report includes traits that match some of these things (e.g., “*breaking problem up into logical parts for studying different failure mechanisms*”). The Analysis level of learning seems to have been reached and documented; however, you need to consider the next possible level, Synthesis.

Synthesis includes activities such as: “*combine ideas into a statement, a plan, a product, etc.*”, “*develop a model*”. The material presented in the documentation (report) shows at least a partial match; you have created the analysis process you used and, further, have explained this process in a report that you also created. Thus, Synthesis is demonstrated; is the Evaluation level justified? Evaluation includes activities such as: “*compare*”, “*choose*”, “*evaluate*”, “*assess*”, etc. If you considered several different analysis methods and selected one of the methods based on a rational set of criteria, then you are operating at this top level; if you did not compare several methods, then you were at the Synthesis level rather than at the Evaluation level for *failure analysis*.

Note: the decision about the higher levels of learning is based primarily on what **was** and **was not** in the report that tied the technical work together, rather than on the **presentation** of the technical work. It is entirely possible that if you were to simply present the technical work, the only conclusion you could reach about the level of

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learning shown would be Application (perhaps only Comprehension if the problem context were not well described).

It is difficult to determine the appropriate affective degree; you must read the descriptions and decide which is appropriate. It will be either Responding or Valuing. If you are a Senior you may have used these failure analysis methods enough to believe they are useful, in which case you are at the Valuing degree. If you do not see them as useful, then you are probably still at the Responding degree.

Problems in Determining the Appropriate Matrix Column

These two brief examples provide a basic guide to selecting appropriate exemplars. These examples also show that the matches between work presented and the various exemplars will not necessarily be exact. You must decide when there are enough matches to justify the claim. Three common questions (with possible answers) relating to this problem are:

1. *When I look at my work and at the definitions of the levels and degrees in Appendix A, I see some matching at a particular level but the match does not seem to be complete.*

This will occur frequently. The material in Appendix A is rather broad and covers a number of different activities that demonstrate that you are operating at the level of interest. It is not expected that your work will match all aspects of these definitions.

2. *It seems to me that I have matches in several different levels or degrees, which one should I claim?*

This will also occur frequently. The levels and degrees are based on taxonomies which means the higher levels and degrees are based on the lower levels and degrees. You will find that the difference between the upper and lower levels and degrees is generally the environment within which you did the work²⁰, or how you present your work, rather than the work product itself. When two levels are possible you should always choose the lower level if the lower level has not already been documented elsewhere (i.e., you have not already placed a page number in the lower box) and the higher level if the lower level has already been documented elsewhere. Generally you cannot use a single work product to simultaneously demonstrate multiple levels of learning for a single competency.

3. *I think that I have been working at a high level but when I look at the work in the Portfolio I do not think it really shows that I am working at the high level.*

This will happen and must be addressed. First, you can discuss this with the course instructor and together identify another opportunity for you to demonstrate the higher level of learning; for example, a verbal demonstration. Alternatively, you might augment your presentation with material that shows you are working at a high level (e.g., a discussion of the process used in defining the solution strategy presented in the work may justify a claim of Synthesis). In the assessment process it is not sufficient that **you** know you have achieved some level or degree, you must supply

²⁰ For example, how much were you told about how to do the work and how much did you have to create yourself.

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documented evidence. Evidence that simply **implies** that you are working at a high level is not as strong or convincing as evidence that **explicitly** shows you are working at the higher levels and degrees.

Step 3 - Completing A Reflection Log (Optional)

After you have some assessment experience, your course instructor may ask you to explain and document your assessment process; i.e., explain how you reached your decision. If this discussion is required, it is placed in a Reflection Log. A Reflection Log is **not** a discussion of the work (a discussion of the work is an expected part of the presentation). Rather, a Reflection Log focuses on the assessment process; on the general characteristics or traits of the work that allow you to match the work with an exemplar. For example, if you were writing a log for the previous bridge design problem and were making a case that the presented work supported a claim of Synthesis level of learning you would need to look in the work product for:

1. the existence of well presented technical work
(see Typical Work Products and Process Verbs for Synthesis),
2. the existence of a report or work that tied all the technical work together
(see Typical Work Products for Synthesis),
3. a discussion that was related to the creation of something.
(see Typical Questions and Process Verbs for Synthesis),
4. the presence (or absence) of material showing that several methods of analysis were considered and the one selected was based on a pre-defined set of criteria.

In the Reflection Log you would indicate where, in the work product, examples of these above four qualities are located. For example, you could note the existence of the report as one of the work products supporting your claim of Synthesis. You would need to refer to sections of the report where the discussion focused on creation (addresses issue 3 above). You would probably also want to note the absence of work products associated with Evaluation.

How many Reflection Logs will be required? This will vary from class to class. It is unlikely that you will be asked to write a reflection log every time you assess your work; however, logs will certainly be regularly required until the course faculty believe that you have developed the skills and knowledge needed to correctly assess work at the level or degree being cited in the log. Note that initially you can expect to write several logs. Until you have extensive experience and practice, it is likely that you will find it difficult to focus on writing about the **assessment** process rather than on the work product itself. The ability to create these logs is a *final opportunity (test)* for you to demonstrate that you are able to do assessment.

Step 4 - Updating the Matrix

The last step in the assessment process is to update the Competency Matrix by entering a page number in one or more of its boxes. Once you file your work in your portfolio and complete the three steps discussed above, you have determined the appropriate matrix column and work page number. The only remaining decision is the appropriate matrix row, i.e., the appropriate competency or learning outcome. This may be determined in one of two ways. First, your instructor may have explicitly told you which competency

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the assignment addresses (e.g., *This assignment is a Comprehension level of learning assignment for differentiation of trigonometric functions.*). In this case you will know exactly which row(s) in the matrix is appropriate for the work product. On the other hand, if the instructor has not provided this information, you will need to determine it yourself.

Look in the matrix for competencies that seem to be related to the task just completed. If you have just completed work on differentiation of polynomials, you need to look for competencies (learning outcomes) such as *differentiation, functions, polynomials*, etc. If you cannot find a Learning Outcome that is associated with the work you have just completed, you need to review the Competency Categories (the rows in the matrix) more carefully to confirm that there are no rows addressing the work product. If you cannot find any row that you believe is related to your work product, you need to discuss this with the course instructor. You are either misinterpreting the meaning of the rows, have done work beyond what was expected by the course instructor, or have discovered a flaw in the assignment.

Course Specific Requirements and Exceptions

The process just discussed is a general process that should be used when you are very comfortable with the process. If this is your first experience with assessment and competency matrices, the course instructors will modify this process so that you can get started. The following modifications are generally used in these introductory classes.

Cognitive Columns

When you update your matrix use the following rules:

- **Knowledge Column**
Enter the page number from a course text book or your class notes where this competency is introduced. If you have Knowledge quizzes on the competency then you may also enter the page number of the graded quiz (located in the Assessment section of your Portfolio or Design Notebook). This box must be filled in before filling in the higher level boxes. If you have work products that are primarily used to show Comprehension but they do have definitions of the competencies as part of the work, then you may enter the page number where the definitions can be found.
- **Comprehension and Application Columns**
Use the general process discussed above. Enter the page number from the work product located in your portfolio or design notebook. Note that two different work products are required to show these two levels (i.e., one work product cannot simultaneously show Comprehension and Application).
- **Analysis, Synthesis, and Evaluation Columns**
In a Freshman class these levels of learning, if achieved, will generally be demonstrated verbally with the issuance of a certificate from the instructor stating that you have successfully demonstrated the level. Enter the page number from the Assessment section of your Portfolio or Design Notebook where you filed this certificate.

If demonstration of these levels is not done verbally, then follow the general procedures, including the writing of a Reflection Log.

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Affective Columns

Collecting demonstration material for the affective boxes is a bit more difficult than for the cognitive boxes. For example, the Valuing exemplar uses terms such as “*believe*” and “*feel*”; these characteristics are difficult to capture in the presentation of your work. Assessment experts do not always agree about what constitutes evidence of these affective behaviors; therefore, you may receive different instructions in different classes or courses. However, in lieu of any other information, when you update the affective boxes you should use the following rules:

- **Receiving**
If you recognize the competency as something you have read or heard about then place a check in the box. You might enter the date you first heard or read about the competency. You must have a competency's Receiving box filled in before you can fill in its Knowledge box.
- **Responding**
If you remember doing an assignment for the competency then you can put a check in the box. You might enter the date you did the assignment in the box. You must have a competency's Responding box filled in before you can fill in its Comprehension box.
- **Valuing**
These boxes are a bit more difficult. Presentations of technical work, even high quality presentations, seldom contain the sort of information that would allow a person to deduce whether or not you valued the process or methods being used. If you believe you have reached this degree of internalization then you will need to prepare a Reflection Log that explains why you have reached this degree.

Two Closing Comments

There are two final issues that need to be addressed to complete this discussion of assessment; (1) how the competency can help you achieve your learning goals efficiently, and (2) the issue of long term achievement of an educational state.

Maximizing Your Opportunities

The Course Competency Matrix, which you received early in the semester, is an outline of what you are expected to learn in the course; these matrices are generally lengthy (twelve pages is not uncommon). Note that you do not need to have a separate assignment for each row of the matrix! With a little creative thought, you can use a single work product to address several rows of the competency matrix. The number of rows you can demonstrate simultaneously with a single assignment will depend on the scope and detail of the initial problem statement.

Specific assignments (e.g., work problem 4.5) are generally given to allow you to demonstrate some small set of competencies at some level of learning. The instructor may tell you which competencies are covered (and perhaps the level as well); if not, you must review the matrix and decide what is appropriate. With a little creative thinking, whether the instructor has given you any information on competencies or not, you can generally see ways to extend the problem slightly and cover more competencies than a first reading of the problem implies. For example, working a problem on differentiation

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of the *sin* function shows Comprehension for this competency; however, if the assigned problem is an implicit function of *sin* you could **also** show implicit differentiation; thus, your single problem addresses **two** rows in the competency matrix.

Not all assignments are as specific as above. You will often be given problems that may be approached in several ways and offer you an opportunity to select what you do (e.g., design problems). In this case the selection of work to do may be motivated by two things: a) a desire to do work that completes the design (task), and b) a desire to do work that can be used to show achievement of course competencies. Before starting such assignments you will want to look at your matrix, determine what areas are lacking and determine if some task that is appropriate for the project is also appropriate for the matrix. You may, in fact, create some work products for the project that were not initially envisioned but that can contribute to the filling in of the matrix. These *extra* work products often give you added insight and are, therefore, useful in the completion of the project.

Learning to recognize the learning potential in an assignment (e.g., learning to transform an assignment to a matrix entry **and** a matrix entry to an assignment) is not intuitive and requires some skill and thought. When you are first learning how to perform self evaluation, the course instructor will discuss how the assignments are related to the matrix and which boxes you should annotate. As your self assessment skills improve, the course instructor will tell you less and less, letting you do more to determine the assignment's potential. You will eventually be able to *mold* the assignment to match your immediate matrix needs.

When Can You Claim Level or Degree Mastery?

If for some competency category you show you can operate at an educational state **once**, does that mean that in this class you would **always** operate at that state? That is, if you were to work a **second** problem using the same competency category would the second effort always be at the same educational state as the first effort? How many times must you perform at some educational state before you can safely claim **retention** of the level (i.e., claim *mastery*²¹ of the educational state?).

If you **do not** subsequently use the competency category items in future classes or work related activities, the educational states you achieve in this class will decay. The engineering curriculum has been developed with an awareness of this time decaying nature of educational states. It has been constructed to provide you with many opportunities, in a series of classes, to use the competencies that are critical to your discipline and, therefore, need to be retained, expanded, and integrated. The expected educational states shown in the Competency Matrix for this class are consistent with either the educational states needed in further classes or the life long levels of performance required of the BS graduate.

²¹ Note this material is using mastery of a competency category at a level or degree and **not** mastery of the category, which generally implies being able to work, unconsciously at the highest cognitive level; i.e., being an expert of the category. *Mastery*, as used in this section, also does **not** have any performance speed attached to the meaning. *Mastery* does **not** mean that you have instant recall or the ability to instantly solve the problem at the educational state claimed.

APPENDIX A

Activities at Various Cognitive Levels of Learning and Affective Degrees of Internalization

Activities at Various Levels of Learning

KNOWLEDGE (INFORMATION)

How do I **know** I have reached this level?

I can recall information about the *subject, topic, competency, or competency area*; I can *recall* the appropriate material at the appropriate time. I have been *exposed* to and have *received* the information about the subject; thus, I can respond to questions, perform relevant tasks, etc.

What do I **do** at this level?

I read material, listen to lectures, watch videos, take notes; I pass 'True/False', 'Yes/No', 'multiple choice', or 'fill in the blank' tests which demonstrate my *general knowledge* of the *subject*. I learn the vocabulary or terminology as well as the conventions or rules associated with the *subject*.

How will the **teacher know** I am at this level?

The teacher will provide *verbal* or *written* tests on the *subject* that can be answered by simply *recalling* the material I have learned about this subject.

What does the **teacher do** at this level?

The teacher directs, tells, shows, identifies, examines the subject or competency area *at this level*.

What are typical ways I can demonstrate my knowledge?

1. Answer 'True/False', 'Yes/No', 'fill in the blank', or 'multiple choice' questions correctly.
2. Define technical terms associated with the subject by stating their attributes, properties, or relations.
3. Recall the major facts about the subject.
4. Name the classes, sets, divisions, or arrangements that are fundamental to the subject.
5. List the criteria used to evaluate facts, data, principles, or ideas associated with the subject.
6. List the relevant principles and generalizations associated with the subject.
7. List the characteristic methods of approaching and presenting ideas associated with the subject (e.g., list the conventions or rules associated with the subject).
8. Describe the general problem solving method (i.e., the techniques and procedures) **or** the method(s) of inquiry commonly used in the subject area.

What are typical *work products*?

1. Answers to Knowledge level quizzes ('True/False', 'Yes/No', 'fill in the blank', or 'multiple choice').
2. Lists of definitions or relevant principles and generalizations associated with the subject.
3. Modifications of example problems presented in the textbook; for example, modest changes in numerical values or units; i.e., solutions to problems which were solved using 'pattern recognition'.

What are descriptive 'process' verbs?

define	label	listen	list	memorize	name
read	recall	record	relate	repeat	view

Modifications by B. McNeill, L. Bellamy, and S. Foster of David L. Langford's definitions of Levels of Learning in, *Total Quality Learning Handbook*, Langford Quality Education; and, B. Bloom et al. *Taxonomy of Educational Objectives*, Longmans, Green and Co., 1956.

Activities at Various Levels of Learning

COMPREHENSION (UNDERSTANDING)

How do I know I have reached this level?

I comprehend or understand the *subject, topic, competency, or competency area*; I use ideas associated with the subject without relating them to other ideas or subjects. I may not yet completely understand the subject. When others are discussing this subject, I can follow and understand the discussion. This level requires **Knowledge**.

What do I do at this level?

I successfully solve textbook problems using appropriate techniques and procedures based on (1) where the problem is located in the book or (2) the problem statement. I translate ideas into my own words (translation from one level of abstraction to another). I translate graphical or symbolic information (e.g., tables, diagrams, graphs, mathematical formulas, etc.) into verbal forms, and vice versa. I interpret or summarize communications (oral/written/graphical). I can use the problem solution to determine effects, trends, implications, corollaries, etc.

How will the teacher know I am at this level?

The teacher will ask questions that can be answered by restating or reorganizing material in a literal manner; i.e., by clearly stating facts or the principle meaning of the material in your own words. The teacher will also give tests based on the textbook problems that were (1) assigned as homework or (2) used as examples in the textbook or in class.

What does the teacher do at this level?

The teacher demonstrates, solves problems, listens, questions, compares, contrasts, and examines the information and your knowledge of the subject.

What are typical ways I can demonstrate, on my own, my comprehension and understanding?

1. Read textbook problems, understand what is required, and successfully solve the problems.
2. Clearly document the process used to solve the problem.
3. Clearly describe the solution to the problem.
4. Draw conclusions based on the solution to the problem.
5. Compare/contrast two different textbook problems (i.e., what elements are the same? what elements are different?).
6. Restate an idea, theory, or principle in your own words.

What are typical work products?

1. Answers to Comprehension level quizzes and exams ('multiple choice' or textbook problems).
2. Solutions to textbook problems which include (a) a summary of the learning objectives associated with the problem, (b) the problem statement in the form of a clearly labeled sketch, specifications, and what is required, (c) a description of the general solution method (techniques and procedures) used to solve the problem, and (d) a discussion of the solution.

What are descriptive 'process' verbs?

describe	discuss	explain	express	identify	locate
recognize	report	restate	review	solve	tell

Modifications by B. McNeill, L. Bellamy, and S. Foster of David L. Langford's definitions of Levels of Learning in, *Total Quality Learning Handbook*, Langford Quality Education; and, B. Bloom et al. *Taxonomy of Educational Objectives*, Longmans, Green and Co., 1956.

Activities at Various Levels of Learning

APPLICATION (INDEPENDENT PROBLEM SOLVING)

How do I know I have reached this level?

I can recognize the need to use an idea, concept, principle, theory, or general solution methods (techniques and procedures) **without being told** and **without any specific or immediate context or cues**. For example, I do not need to locate a similar example in a textbook, nor do I need to know that an assignment is for a particular course in order to recognize the need to use a particular idea, etc. I know and comprehend these ideas, concepts, principles, theories, or general solution methods (techniques and procedures) and I can apply them to new situations. I also have the ability to recognize when a certain task or project is beyond my current competency. This level requires **Knowledge and Comprehension**.

What do I do at this level?

I apply ideas, concepts, principles, theories, or general solution methods (techniques and procedures) that I learned at the Knowledge and Comprehension level to new situations. I solve problems in which the solution method is not immediately evident or obvious. I solve these problems independently and make use of other techniques and procedures as well. This requires not only knowing and comprehending these ideas, concepts, principles, theories, and general solution methods (techniques and procedures) but deep thinking about their usefulness and how they can be used to solve new problems that I identify or define.

How will the teacher know I am at this level?

The teacher will review my work products and confirm that I am solving problems independently, in new situations, and without prompting by the teacher. The teacher will be able to pose general questions such as *"How much protection from the sun is enough?"* and I will know how to answer the question by defining and solving a problem.

What are the typical ways I can demonstrate, on my own, my Application of Knowledge and Comprehension?

1. Solve problems which require that I recognize and apply the appropriate ideas, concepts, principles, theories, general solution methods (techniques and procedures), etc. **without being told** and **without any specific or immediate context or cues**.
2. Apply the laws of mathematics, chemistry, and physics, as well as engineering, business or design concepts, etc. to practical problems or situations.
3. Solve problems associated with *design/build* projects.

What are typical work products?

1. Application level work products are very similar to Comprehension level work products; however, documentation will be included which demonstrates that you recognized the need to use ideas, concepts, principles, theories, general solution methods (techniques and procedures), etc. in a new situation.

What are descriptive process verbs?

apply	demonstrate	employ	illustrate	interpret
operate	practice	recognize	solve	use

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Activities at Various Levels of Learning

ANALYSIS (LOGICAL ORDER, COMPONENTS)

How do I know I have reached this level?

I can explain *why*. I can methodically examine ideas, concepts, principles, theories, general solution methods (techniques and procedures), reports, etc. and separate these into their component parts or basic elements. I can use the results of this examination to clarify the organization of the whole or to gain a global view. This level requires **Knowledge** and **Comprehension** Levels of Learning; **Application** is **not** required.

What do I do at this level?

I demonstrate that I can analyze results by breaking ideas, concepts, principles, theories, general solution methods (techniques and procedures), reports, etc. into their component parts. I explain the logical interconnections of the parts. I can also develop detailed cause and effect sequences.

What does the teacher do at this level?

The teacher probes, guides, observes, and acts as a resource or facilitator.

What are typical questions I can ask myself that will demonstrate my Analysis Level of Learning?

1. What are the causal relationships between the parts and how the whole functions?
2. Can I explain, from the parts, why the whole does or does not work?
3. Are the conclusions supported by sound reasoning?
4. Does the evidence provided support the hypothesis or the conclusion?
5. Are the conclusions supported by facts, opinions, or an analysis of the results?
6. What are the unstated assumptions, if any?

What are typical work products?

1. Answers to Analysis level exams (problems, multiple choice, essays).
2. Analysis level work products are very similar to Comprehension level work products; however, documentation will include a more extensive discussion of the work. The content, amount, and depth of the presentation are what distinguish Analysis level work products from Comprehension level work products; e.g., see items 1. through 6. above.

What are descriptive process verbs?

analyze	appraise	break apart	break down	calculate
compare	contrast	debate	diagram	differentiate
examine	experiment	explain	inspect	inventory
question	relate	solve		

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Activities at Various Levels of Learning

SYNTHESIS (CREATE)

How do I know I have reached this level?

I have the ability to assemble parts and elements into a unified organization or whole that requires original or creative thinking. I recognize new problems and develop new tools to solve them. I create my own plans, models, hypotheses, etc. for constructing solutions to problems. This Level of Learning requires **Knowledge, Comprehension, Application** and **Analysis** Levels of Learning.

What do I do at this level?

I generate ideas and use them to create a physical object, a process, a design method, a written or oral communication, or even a set of abstract relations (e.g., mathematical models). I produce written or oral reports that have the desired effect (e.g., information acquisition, acceptance of a point of view, continued support, etc.) on the reader or listener. I generate project plans. I propose designs. I formulate hypotheses based on the analysis of relevant or pertinent factors. I am able to generalize from a set of axioms or principles.

How will the teacher know I am at this level?

I demonstrate that I can combine ideas into a statement, a plan, a product, etc. that was previously unknown to me; e.g., I develop a program that includes the best parts of each of these ideas.

What does the teacher do as this level?

The teacher reflects, extends, analyzes, and evaluates.

What are the typical questions I can ask myself that will demonstrate my Synthesis Level of Learning?

Can I create a project plan?

Can I develop a model?

Can I propose a design?

What are typical work products?

- Answers to Synthesis level exams (problems, multiple choice, essays).
- Synthesis level work products are very similar to Comprehension level work products; however, documentation will include a more extensive discussion of the work. The content, amount, and depth of the presentation are what distinguishes Synthesis level work products from Comprehension level work products; e.g., see items 1. Through 3. Above.

What are descriptive process verbs?

Arrange	assemble	collect	compose	construct
create	design	formulate	manage	organize
plan	prepare	propose	set up	write

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Activities at Various Levels of Learning

EVALUATION (APPRECIATION)

How do I know I have reached this level?

I have the ability to judge and appreciate the value of ideas, concepts, principles, theories, or general solution methods (techniques and procedures) using appropriate **criteria**. This level requires **Knowledge, Comprehension, Application, Analysis, and Synthesis** Levels of Learning.

What do I do at this level?

I make value judgments based on certain criteria such as usefulness and effectiveness. Based on information gained through application, analysis, and synthesis, I can rationally select a process, a method, a model, a design, etc. from among a set of possible processes, methods, models, designs, etc. I evaluate competing plans of action before actually starting the work. I evaluate work products based on **internal** standards of consistency, logical accuracy, and the absence of internal flaws; e.g., I can certify that the feasibility of a design has been demonstrated in a report. I evaluate work products based on **external** standards of efficiency, cost, or utility to meet particular goals or objectives; e.g., I can certify that the quality of the design has been demonstrated in a report.

How will the teacher know I am at this level?

I demonstrate that I can select, judge, or appreciate a process, a method, a model, a design, etc. using appropriate criteria or standards.

What does the teacher do at this level?

The teacher clarifies, accepts, harmonizes, aligns, and guides.

What are typical statements and questions I can answer to that will demonstrate or show my appreciation/evaluation?

1. I can evaluate an idea in terms of ...
2. For what reasons do I favor...?
3. Which policy do I think would result in the greatest good for the greatest number?
4. Which of these models or modeling approaches is best for my current needs?
5. How does this report demonstrate that the design is feasible?
6. How does this report demonstrate the quality of the design?

What are typical work products?

1. Answers to Evaluation level exams (problems, multiple choice, essays).
2. Evaluation level work products are very similar to Comprehension level work products; however, documentation will include a more extensive discussion of the work. The content, amount, and depth of the presentation are what distinguish Evaluation level work products from Comprehension level work products; e.g., see items 1. through 6. above.

What are descriptive process verbs?

appraise	assess	choose	compare	estimate (quality)
evaluate	judge	predict (quality)	rate value	select

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RECEIVING (ATTENDING)

The degree of Receiving ranges from simple awareness, to a willingness to receive, and finally to controlled or selected attention. You must first become aware of ideas, concepts, principles, theories, or general solution methods (techniques and procedures), etc. before you can decide whether you are willing or able to receive these ideas, etc. You must then determine whether these ideas, etc. are important enough to warrant your controlled or selected attention.

What do I do at this degree?

At this degree of internalization, I am only concerned about my conscious recognition of the existence of certain phenomena and stimuli; i.e., I am willing to receive or attend to these phenomena and stimuli. I am willing to listen to lectures, read books, or watch videos and am aware²² of the material being presented in the lectures, books, or videos²³. I have prepared notes or sketches related to the presentation.

How do I know I have reached this degree?

At the end of a lecture, book or video, I can select, from a set of topics, the topics that were presented. I can list or briefly summarize important points from the presentation.

What are descriptive process verbs?

concentrate	feel (touch)	listen
pay attention	read	recognize
remember	smell	watch

²² Does not imply a Comprehension or Knowledge Level of Learning only an Awareness Degree of Internalization.

²³ N.B. A **willingness** to receive does **not** ensure that you **are** receiving. You do not come to class *de novo*. You may have a point of view based on previous formal or informal experiences that may facilitate or hinder your ability to recognize the material presented by the teacher. Even when you **are willing** to **receive** the material, these *a priori* points of view (also referred to as paradigms or learning styles) may limit your ability to **attend**; this inability to **attend** prevents you from **receiving** the material.

RESPONDING

The degree of Responding ranges from merely agreeing to respond, to a willingness to respond, and finally to feeling some satisfaction from responding to directions, requests, ideas, concepts, principles, theories, or general solution methods (techniques and procedures), etc.

What do I do at this degree?

I learn by doing²⁴. I answer questions in class when called upon by the instructor. I perform the tasks assigned by the instructor; e.g., solve homework problems. I ask questions in class. I attend and participate in team meetings organized by the instructor. Outside of class, I spontaneously discuss course material with classmates and especially with friends who are not classmates. I prepare notes on my reading assignments. I reorganize and integrate my class notes with my notes on the reading assignment. I participate in the learning activities both inside and outside the classroom. I make a reasonable effort to find the class material relevant, interesting, and useful. I may use the class material as the basis of written or oral reports in other classes ²⁵.

How do I know I have reached this degree?

I feel comfortable with my team; i.e., I know that I am contributing at least what is expected of me by my teammates. I meet the class deadlines. I invest the level of effort that is expected for this class. I attend class regularly and arrive on time. I have work products for the class that are well organized and accessible.

What are descriptive process verbs?

calculate	discuss	draw
integrate	make	organize
play	sketch	talk
write		

²⁴ Paradigms can affect what you actually receive; similarly, fear can keep you from responding even when you are *willing*; e.g., fear of failure (as judged by an instructor or peer), fear of looking foolish, fear of ridicule, fear of missing the point, fear of punishment, fear of a poor grade. Fear is a powerful, extrinsic **DE**motivator that you must address before you can reach the Responding Degree of Internalization.

²⁵ Responding is still a rather low level of commitment; it would be incorrect to say that you *value* the material or that you actively displayed a *positive attitude* toward the material.

VALUING

The degree of Valuing ranges from simply accepting the values presented by the instructor, to preferring these values, and finally to making a commitment to these values. The values which are relevant in this context are the directions, requests, ideas, concepts, principles, theories, or general solution methods (techniques and procedures), etc. specified in the course syllabus or presented by the instructor.

What do I do at this degree?

I frequently solve problems using the knowledge, skills, abilities, methods, etc. that I have learned. I may try to teach what I know to people who are not familiar with the material or to people who are having difficulty understanding the material. I use the material in activities unrelated to this class. I form or participate in study groups to improve my understanding of the material. I may challenge people who are skeptical about the material in an effort to help them eliminate or at least reduce their skepticism.

How do I know I have reached this level?

I believe the material I have learned is useful and helps me solve problems; I can justify or explain this belief both to myself and to others. I make a concerted effort to obtain more information about the class material; e.g., I obtain additional books, watch extra videos, attend other classes or seminars, etc. I am concerned when people express their skepticism or doubts about the material and its value or usefulness. I am comfortable working in teams or working alone. I am interested in the class material and demonstrate curiosity, honesty, integrity, and candor in dealing with others and in the work products or deliverables I produce for the class.

What are descriptive process verbs?

care convince use

APPENDIX B

Competency Matrix
Work Log Template
Sample Run Chart

Sample Competency Matrix

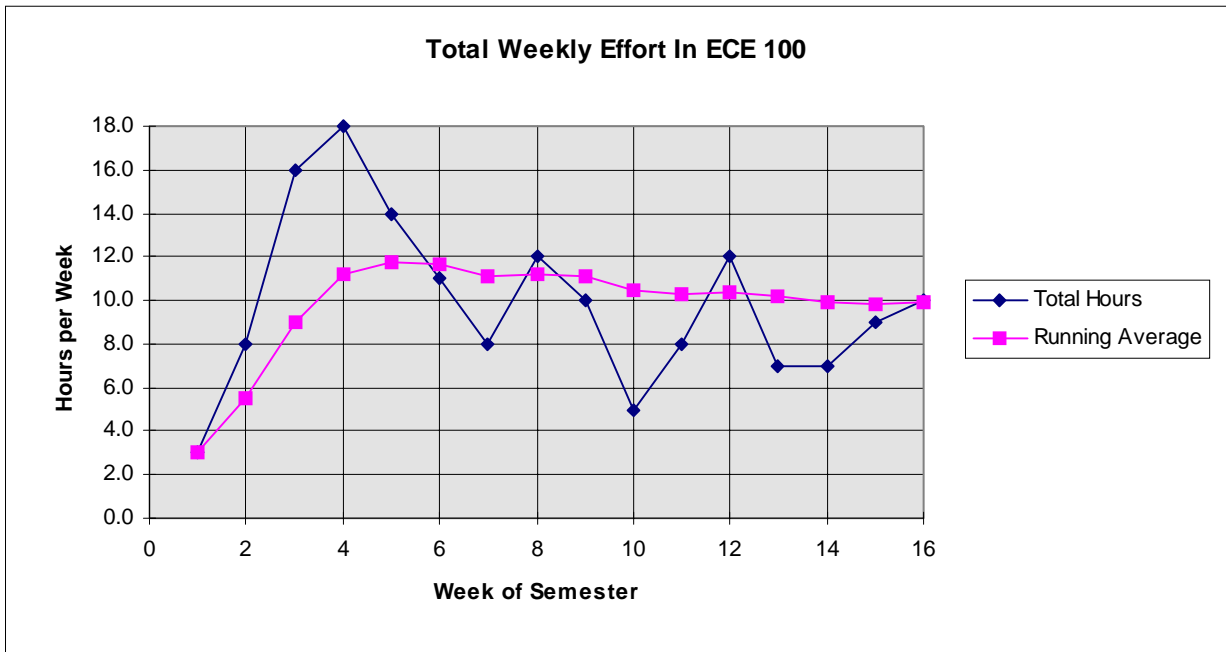
Entering Class	●	During Class		Affective Degree			Cognitive Level				
Learning Outcomes	Competency Categories	comp #	Receiv- ing	Respond- ing	Value- ing	Knowl- edge	Compreh- ension	Appli- cation	Analy- -sis	Syn- thesis	Evalua- tion
1. differentiation	exponential functions	1.1	2	3		2	3				
	hyperbolic functions	1.2	2	3		2	3				
	implicit	1.3	3	4		3	4				
	polynomials	1.4	●	2		1	2				
	trigonometric functions	1.5	4	5		4	5				
2. team meetings	code of cooperation	2.1	1	2		1	2				
	constructive feedback	2.2	7			7					
	devils advocate	2.3	2	1		2	3				
	gatekeeper	2.4	2	1		2	3				
	norms	2.5	4			4					
	team facilitator	2.6	2	1		2	3				
	team leader	2.7	2	1		2	3				
	team member	2.8	2	1		2	3				
	time keeper	2.9	●	1		●	3				

Work Log Template

[illegible]

Work Code	Definition	Work Code	Definition
1.	team meeting	5.	laboratory technical task
2.	modeling	6.	design notebook
3.	reading/research	7.	team maintenance
4.	using computer	8.	

Example Run Chart



Week	Total Hours	Running Average	
1	3.0	3.0	
2	8.0	5.5	
3	16.0	9.0	
4	18.0	11.3	
5	14.0	11.8	
6	11.0	11.7	
7	8.0	11.1	
8	12.0	11.3	
9	10.0	11.1	
10	5.0	10.5	
11	8.0	10.3	
12	12.0	10.4	
13	7.0	10.2	
14	7.0	9.9	
15	9.0	9.9	
16	10.0	9.9	

APPENDIX C

A Simple Mechanics Problem with Three Solutions

The Context for the Work Product or Problem Solution

The work products representing several solutions to the problem below are presented on the following pages.

The **first** work product or solution on page J - 68 is for a homework assignment submitted in an introductory statics course. The instructor specified the presentation format for the solution.

The **second** work product or solution on page J - 69 was prepared during the Fundamentals or Engineering Exam. The problem was included in the Mechanics section of the exam.

The **third** work product or solution on page J - 70 was prepared as an example problem for an introductory mechanics (or statics and dynamics) textbook.

The Problem

You rent an inexpensive truck for 2 hours and invite your friend Bubba to help you move a refrigerator and several other items to a new apartment. Bubba is injured when the refrigerator tips over backwards and falls on him as you attempt to push the refrigerator across the floor (see Figure 1). After taking Bubba to the emergency room at a nearby hospital, you return to finish the job. However, before you attempt to push the refrigerator across the floor, you decide to determine what caused the accident in the first place. (You may also be concerned that Bubba may decide to sue you and the truck rental company for providing an unsafe working environment!)

How hard do you have to push? What should you do to get the refrigerator started moving across the floor safely? Assume that the coefficients of static and dynamic friction are 0.2 and 0.1 respectively, the refrigerator is 2.0 meters high, 1.0 meter wide, and 1.0 meter deep, the refrigerator weighs 100.0 kilograms, and you may assume that the center of gravity of the refrigerator is at the geometric center of the refrigerator. State any assumptions that you make and draw a box around your answer.

First Solution

This problem is similar to the problem in Example Problem 3.2 on p. 140 in the text book.

Given:

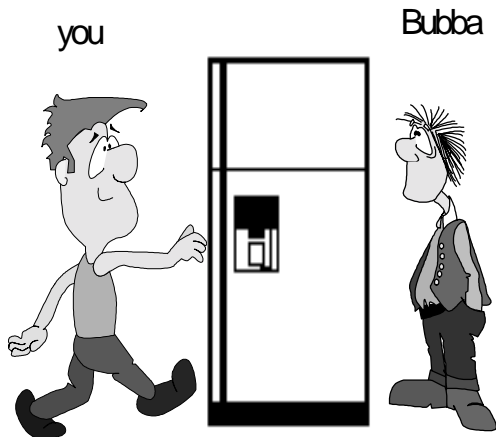
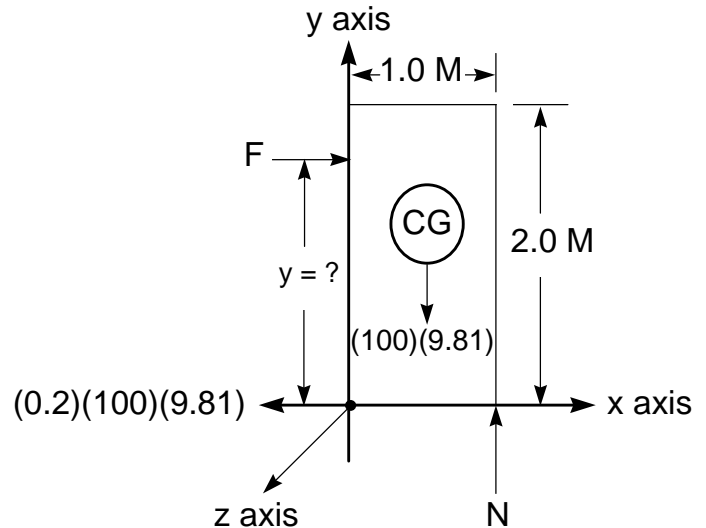


Figure 1 : Moving the Refrigerator



Required: $y = ?$ when the refrigerator begins to 'tip'.

Solution:

$$N - (100.0)(9.81) = 0, \quad N = 981.0 \text{ newtons}, \quad F - 0.2 N = 0$$

$$-(y)(0.2)(981.0) - (0.2)(981.0)(1.0) + (981.0)(0.5) = 0$$

$$F = (0.2)(981.0) = 196.2 \text{ newtons}$$

$$y = 1.5 \text{ meters}$$

Therefore, I can push the refrigerator safely if I do not apply the force more than 1.5 meters above the floor.

Second Solution

Specifications:

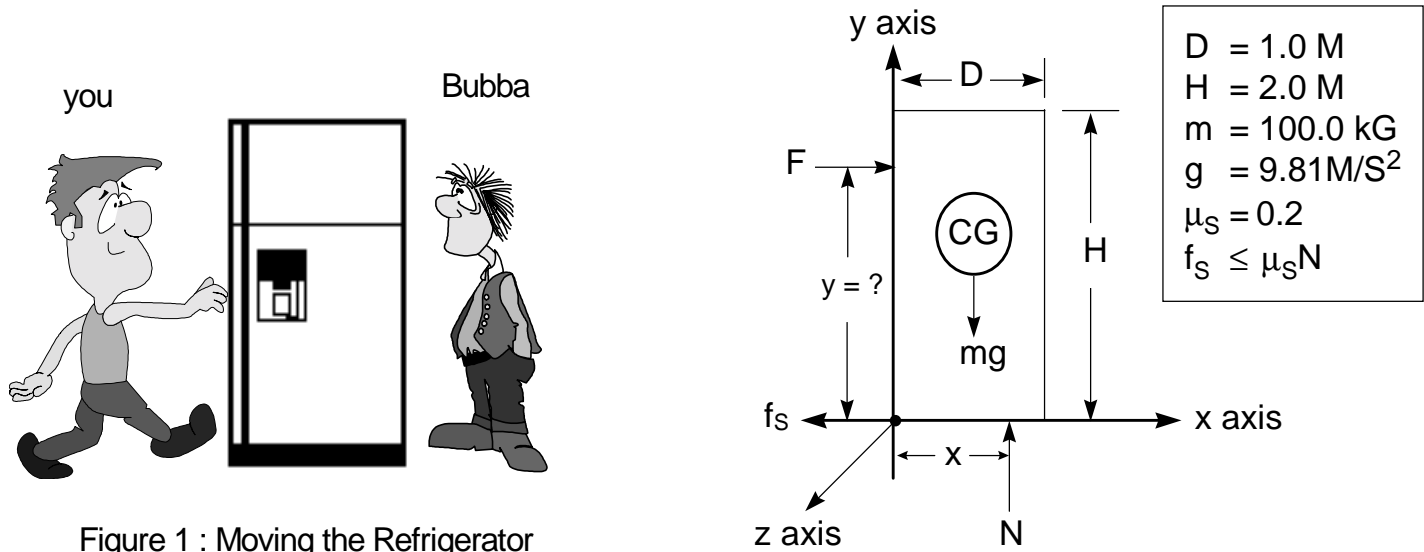


Figure 1 : Moving the Refrigerator

Required : $y = ?$ when the refrigerator begins to 'tip'.

Solution:

This problem involves impending motion, friction forces, a 'force balance' in both the x and y directions, and a torque balance. The normal force can be determined from a 'force balance' in the y direction or $N - mg = 0$. The frictional force in the x direction is defined as $f_s \leq \mu_s N$. For impending motion, $f_s = \mu_s N$. Furthermore, $F - f_s = 0$ from a 'force balance' in the x direction, and $-Fy - f_s \left[\frac{H}{2} \right] + N \left(x - \frac{D}{2} \right) = 0$ from a 'torque balance' in the z direction about the center of gravity. The maximum value of x is 1.0 meter if the bottom of the refrigerator is to remain in contact with the floor; thus, F and y can be determined from the equations above.

$$F = \mu_s mg \quad \text{and} \quad y = \left[\frac{1}{\mu_s} \right] \left[x - \frac{D}{2} \right] - \left[\frac{H}{2} \right]$$

$$F = (0.2) (100.0) (9.81) = 196.2 \text{ newtons}$$

$$y = \left[\frac{1.0}{0.2} \right] \left[1.0 - \frac{1.0}{2} \right] - \left[\frac{2.0}{2} \right] = 1.5 \text{ meters}$$

Therefore, I can push the refrigerator safely if I do not apply the force more than 1.5 meters above the floor.

Third Solution

Specifications:

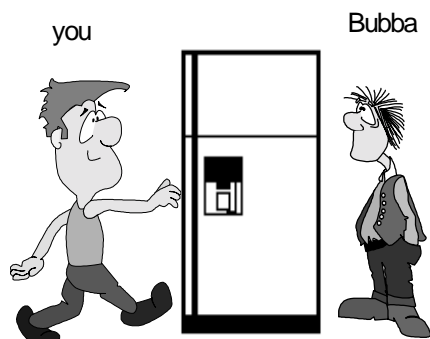
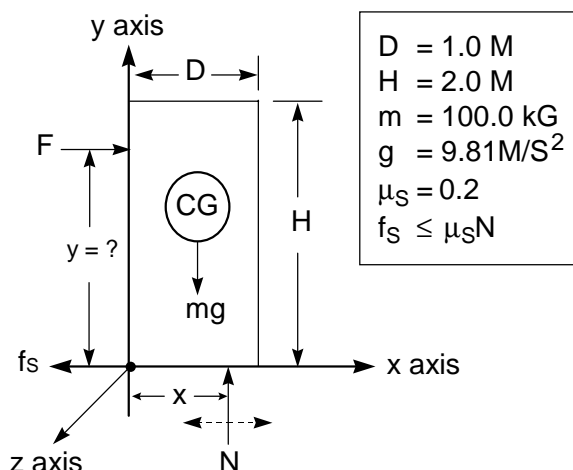


Figure 1 : Moving the Refrigerator



Required : $y = ?$ when the refrigerator begins to tip'

Content and Discussion:

This is a traditional 'Will it tip, rotate, or slip?' problem. The objective in this particular problem is to determine where to apply the force to slide the refrigerator across the floor safely; i.e., to avoid causing the refrigerator to tip or rotate and injure someone nearby. The solution will probably include a range of applied forces and locations which make this possible. Since rotational friction has not been discussed prior to this problem, the refrigerator will be represented as a two dimensional object in the sketch below. The conservation of linear momentum in both the x and y directions will be used in the analysis as well as the conservation of angular momentum in the z direction and the defining relations for the frictional forces. The center of gravity is the most likely reference point for angular momentum since the weight term for the refrigerator can be eliminated from the conservation equation (i.e., the radius associated with the weight term is zero!) and the accumulation term only includes the angular velocity; this is a common practice in elementary problems. First, a clearly labeled sketch should be prepared which shows all of the explicit and implicit specifications included in the problem. For example, note that the 'equivalent' normal force is located at an arbitrary point on the x axis and dotted arrows are used to denote that this location can change as the applied force changes; the normal force, like pressure, acts on the entire surface, but an 'equivalent' location is used in the angular momentum equation. Finally, the initial motion of the refrigerator will be modeled to determine the limits on the magnitude and location of the applied force required for stable operation or safe movement.

Analysis:

The conservation of linear momentum in the y direction can be used to determine the normal force; i.e.,

$$N - mg = \frac{d(m v_y)}{dt}$$

where v_y is the velocity of the center of gravity of the refrigerator and

$$v_y \equiv \frac{d(y_{CG})}{dt}.$$

Solutions to a Simple Mechanics Problem

Furthermore, both $v_y = 0$ and $\frac{d(m v_y)}{dt} = 0$ if the bottom of the refrigerator remains in contact with the floor. The conservation equation can be solved for the normal force; i.e., $N = mg$.

The conservation of linear momentum in the x direction can be used to determine the force required to overcome the static friction between the floor and the refrigerator;

i.e., $F - f_s = \frac{d(m v_x)}{dt}$, where v_x is the velocity of the center of gravity of the refrigerator

and $v_x \equiv \frac{d(x_{CG})}{dt}$.

The frictional forces between the refrigerator and the floor will be in the x direction; they are defined as $-\mu_s N \leq f_s \leq \mu_s N$ and $-\mu_D N \leq f_D \leq \mu_D N$ respectively.

For impending motion, $f_s = \mu_s N$ and $\frac{d(m v_x)}{dt} = 0$; i.e., there is no motion in the x

direction. Thus, the conservation equation can be solved for the force required to overcome static friction; i.e., $F = f_s = \mu_s mg$.

The conservation of angular momentum about the center of gravity in the z direction can be used to determine the maximum height at which the force can be applied without 'tipping' the refrigerator; i.e., $-F y - f_s \left[\frac{H}{2} \right] + N \left(x - \frac{D}{2} \right) = \frac{d(I_{CG} \omega_z)}{dt}$, where I_{CG} is the moment of inertia of the refrigerator about the center of gravity and ω_z is the angular velocity in the z

direction. For impending motion, again $f_s = \mu_s N$. Furthermore, $\frac{d(I_{CG} \omega_z)}{dt} = 0$ if the

refrigerator does not tip or rotate. The conservation equation can now be solved for the height at which the force can be applied without 'tipping' the refrigerator;

i.e., $y = \left[\frac{1}{\mu_s} \right] \left[x - \frac{D}{2} \right] - \left[\frac{H}{2} \right]$. Note that there are two unknowns in this equation, y and

x . However, the maximum value of x is D and the minimum value is zero; i.e., the 'equivalent' normal force must occur at a point on the body. A cursory inspection of the equation above reveals that the maximum value of x corresponds the maximum value of y . This conclusion is also obvious from a cursory review of the sketch above. Thus, the conservation equation can be solved for y_{\max} , the maximum height at which the force can be applied without 'tipping' the

refrigerator; i.e., $y_{\max} = \left[\frac{D}{2 \mu_s} \right] - \left[\frac{H}{2} \right]$. Note that the minimum value of y is zero since a

negative value of y results from solving the conservation equation at $x = 0$.

$$F = f_s = \mu_s mg = (0.2)(100.0)(9.81) = 196.2 \text{ newtons}$$

$$y_{\max} = \left[\frac{D}{2 \mu_s} \right] - \left[\frac{H}{2} \right] = \left[\frac{1.0}{(2)(0.2)} \right] - \left[\frac{2.0}{2} \right] = 1.5 \text{ meters}$$

Therefore, I can push the refrigerator safely if I do not apply the force more than 1.5 meters above the floor.

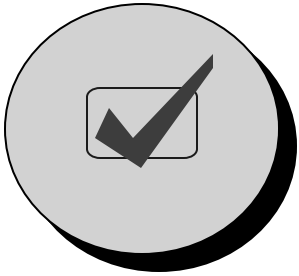
Note that the maximum height is **not** dependent on the **weight** of the refrigerator; i.e., it is only dependent on the **geometry**, or D and H , and the coefficient of static friction, or μ_s ! This seems reasonable since the normal force, N , is equal to the weight?

SECTION K

Tool Box

The slides in this section are used to present various quality discussion tools. These discussion tools are very useful in helping teams achieve consensus. Some of these tools have already been introduced in other sections of this workbook. After students have some experience working with thier teams, they should browse through these tools to determine if any of them might be useful in accomplishing subsequent team assignments.

More detailed comments on the topics of these slides can be obtained by viewing the "notes pages" of the original PowerPoint files(s), available on the course website.



Useful Team Processing Tools

A number of tools have been developed to provide a structure which facilitates team discussion, exploration of ideas, and decision making. Examples include:

Seven Management and Planning Tools

Activity Network Diagram
Interrelationship Digraph **
Prioritization Matrix **
Tree Diagram **

Affinity Diagram **
Matrix Diagram **
Process Decision Program Chart

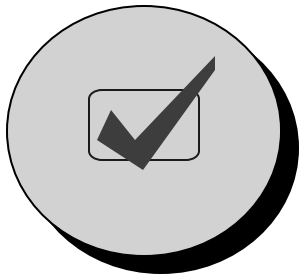
Others

McNeill's Agenda Planner **
Brainstorming **
Deployment Flow Chart **
Force Field Analysis **
Impact/Changeability (9-Block) **
Issue Bin **
Nominal Group Technique **
P.E.R.T. Chart
Radar Chart
Stability Chart

Assignment Matrix **
Consensogram
Fishbone Diagram
Histograms
Integrative Analysis Diagram
Multivoting **
Pareto Chart
Process Check **
Run Charts

** Information available in this workbook

Source: The Memory JoggerPlus+, GOAL/QPC, 13 Branch Street,
Methuen, MA 01844. 508-685-3900, Fax 508-685-6151

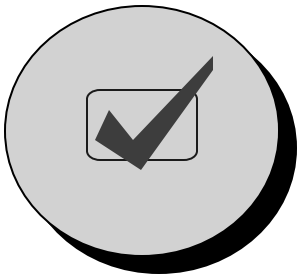


McNeill's Agenda Planner

Time Block (minutes)		Meeting Date
From To	Details	
Duration		Meeting Location
Topic		
Participants		Team Leader
Purpose		
Cognitive Goals		Team Recorder
		Team Facilitator
Affective Goals		Team Time Keeper
Discussion Tools or Activity		Team Devil's Advocate
Required Reading or Preparation		
Visual/Audio /Other Aids/Equipment		



K - 3



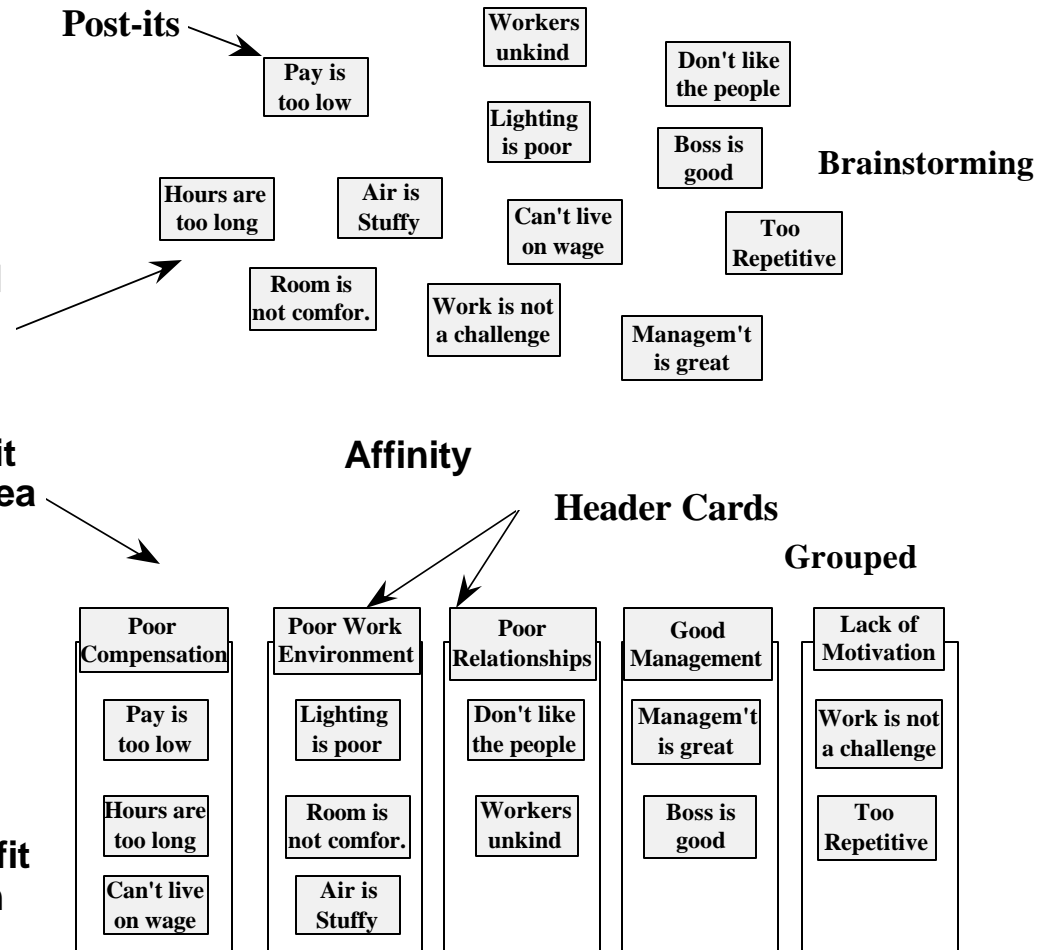
Brainstorming and Affinity Processes

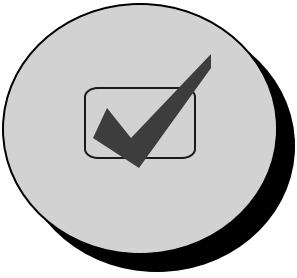
Purpose:

- ❖ To organize a large set of items into a smaller set of related items.

Guidelines:

- ❖ The rules of brainstorming are followed but each idea is written (in 7 words or less, including a noun and a verb) on a self-adhesive Post-it note or card.
- ❖ Team members silently move the Post-it cards around to form closely-related idea groups.
- ❖ If disagreement exists when grouping, make copies of the contested card and place in more than one group.
- ❖ Label each group with a *header card* which clearly identifies and reflects the theme of the cards.
- ❖ If there are single idea cards that don't fit well with the other ideas, have the team decide if they should be kept (they may be excellent ideas thought of only by one person).





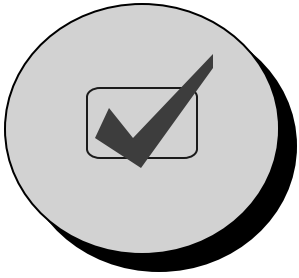
Affinity Process

Purpose

To organize large sets of items (more than twenty items) into smaller sets of related items.

Steps

1. The rules of brainstorming are followed but each idea is written (in seven words or less using a verb and a noun) on a self-adhesive Post-it note or card.
2. After all the ideas have been generated and entered on the Post-its, post all the Post-its on a wall or board. Discuss the Post-its to determine if there are any questions about what any of the Post-its say or mean.
3. Team members now silently move the Post-it cards around, grouping cards that have an affinity together.
4. If disagreement exists when grouping, make copies of the contested card and place in more than one group.
5. When the grouping has stopped, discuss each grouping to determine what it is that relates all the cards. Write a header card for each group that captures the theme and feeling of the cards.
6. If there are single idea cards that do not fit well with the other ideas, have the team decide if they should be kept.



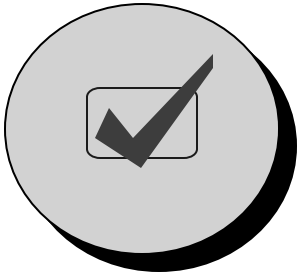
Brainstorming

Purpose

To generate a high volume of ideas in a non-analytical manner which permits the ideas of one individual to stimulate the ideas of the other individuals in the team.

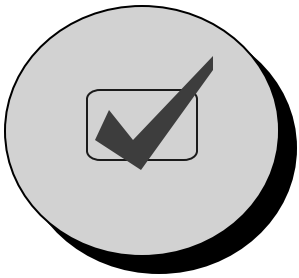
Steps

1. Define and write out a question (topic) for which you desire a large number of answers.
2. Silently generate and write down a list of ideas. When it seems most team members have stopped adding to their lists, share the lists and continue to generate ideas as they occur.
3. Record the information as given (i.e., do not paraphrase).
4. Do not criticize ideas or people.
5. Strive for fluency of ideas by building (piggybacking) on the given ideas.
6. Strive for a maximum number of ideas.
7. Strive for flexibility of ideas. Welcome wild ideas which can act as triggers to stimulate breakthroughs into new directions.



Steps in Creating a Deployment Flowchart

1. Identify steps for completing the process in the order they occur.
2. Use flowcharting symbols to diagram the steps in the process.
3. Connect the symbols with arrows indicating process flow.
4. Rework the flowchart by adding the people dimension.
5. Stretch meeting ovals to include all meeting participants
6. Draw rectangular symbols under person of primary responsibility; indicate input of others by use of circular symbols under their names connected with a line and arrow to the rectangular symbol.
7. Place decision diamond-shaped symbols under individual involved in the decision process.



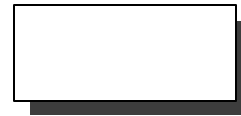
Symbols Used in Flowcharts



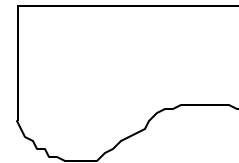
meeting



task



multiple task



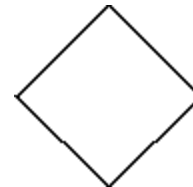
document



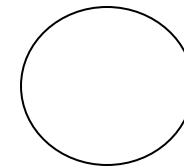
standard process



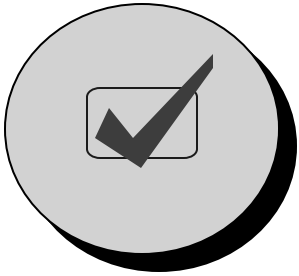
termination
of process



decision



assistance or
involvement



Force Field Analysis

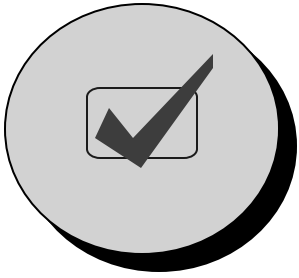
Purpose

A force field analysis helps teams find out what is driving, slowing, or preventing change. The tool helps a team to work together, to find a starting point from which to take action, and to show both sides of the change issue.

Steps

1. On a board or large piece of paper draw a vertical line down the middle and a horizontal line across the paper near the top.
2. Label the left column Promoting and the right column Preventing.
3. Brainstorm entries for the left hand column.
4. Brainstorm entries for the right hand column.

Promoting	Preventing



Impact Changeability Analysis

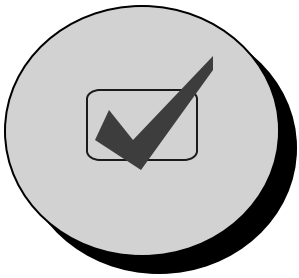
Purpose

This tool helps prioritize a set of options.

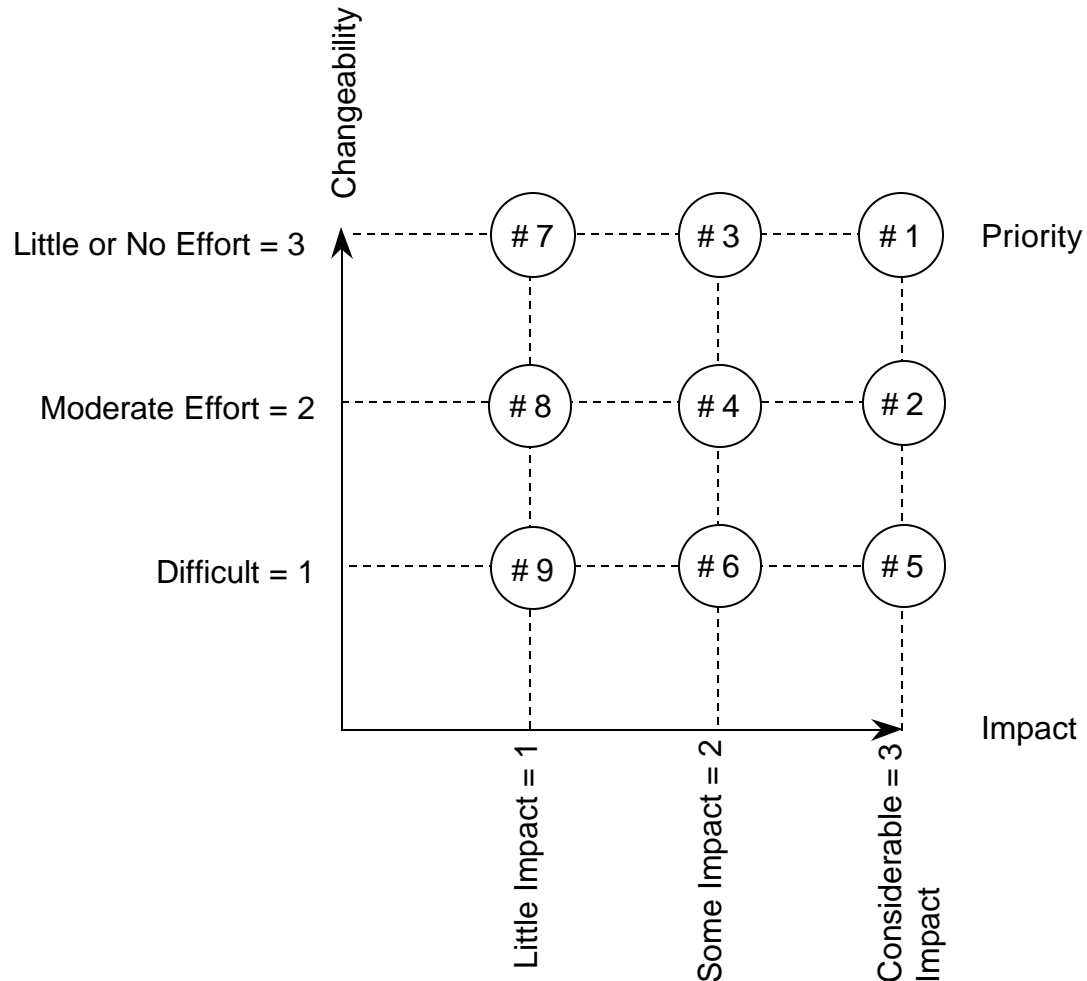
Steps

1. Review the tables on the next page for possible meanings of:
Impact and Changeability
2. Rank each option on impact and changeability using the following scales:
If the option were implemented (or problem eliminated)
what impact would this have?
 1 = Little Impact
 2 = Some Impact
 3 = Considerable Impact

How difficult will it be to implement the option (or eliminate the problem)?
 1 = Difficult
 2 = Moderate Effort
 3 = Little or no Effort
3. Use the chart on the next page to determine the relative priority of the options.

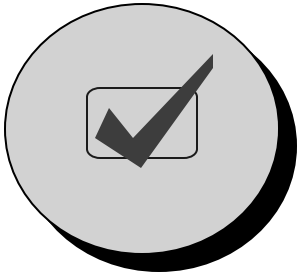


Impact Changeability (cont.)



Impact Considerations
Effect on quality
Time savings
Material savings
Morale
Number of people who benefit

Changeability Considerations
Resource requirements
Complexity of investigation
Time required
Ability to measure outcomes
Number of decision making levels required



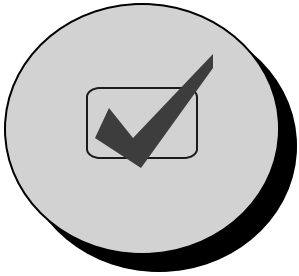
Interrelational Digraph

Purpose

To help understand the interrelationships which exist among the various aspects of a problem and highlight potential root causes and bottlenecks.

Steps

1. Select an appropriate issue (e.g., one that has at least fifteen interrelated issues which need to be better defined).
2. Generate the list of issues (e.g., brainstorm, header cards from Affinity Process, bones from a Fishbone Diagram), placing each issue on a 3 x 5 Post-it.
3. Arrange the Post-its around the edge of a large circle, drawn either on a board or flip chart paper.
4. Number the Post-its, clockwise around the circle.
5. Starting with Post-it #1, ask the following question for each of the other Post-its: Does the issue listed on Post-it #1 influence or cause the issue listed on Post-it #n?
6. Whenever the answer to the question posed in 5 is yes draw an arrow from 1 to the Post-it which is influenced or caused by 1.
7. Repeat steps 5 & 6 using a different starting Post-it until all the Post-its have been used for starting the process.
8. Count the arrows leaving and entering the Post-its. Post-its which have a large number of arrows leading from the Post-it are potential Root Causes; while Post-its which have a large number of arrows leading to the Post-it are potential bottlenecks.



Matrix Diagram

(for an example, see the Assignment Matrix on page K-3)

Purpose

To help show relationships or requirements which exist among lists of items, requirements, criteria, resources, or people.

Steps

1. Select an appropriate issue (e.g., one that has several lists of interrelated items).
2. Select the right type of matrix (e.g., an L matrix to relate two lists, a Y or T matrix to relate three lists, an X matrix to relate four lists).
3. Select an appropriate set of symbols and create a legend for the symbols, for example.

⊙ The two items are strongly related

○ The two items are somewhat related

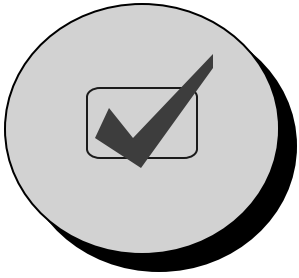
△ The two items are not related

P This person has primary responsibility

S This person has secondary responsibility

△ This person needs to be kept informed

4. Fill in the matrix using the agreed upon symbols.
5. Interpret the matrix (interpretation will depend on why matrix was created, e.g., are all tasks assigned, is there one issue that is strongly related to a number of items, etc.).



Modified Nominal Group Technique

Purpose

Modified nominal group technique is a technique to help a team or group quickly reduce a large list of items to a smaller number of high priority items. The process elicits a high degree of team agreement and promotes team ownership. This tool is similar to nominal group technique but not quite as involved.

Steps

Step 1

Count the number of items on the list and divide by three. This is the number of votes each person has. (Round fractions off to the lower number.) If the items number more than 60, do not go over a vote total of 20. Vote totals of more than 20 are hard to manage. Give each team member as many colored dots as she/he has votes.

Step 2

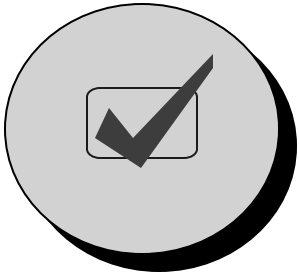
Have each person use his/her votes (colored dots) to select the items he/she wants to keep. While each person can vote for any item, it is a good idea to limit the number of votes any one item can receive from a single person to three. Note: the team can decide if they want to allow more or less multiple voting.

Step 3

List alternatives in their new prioritized order.

Step 4

Critically discuss the top alternatives in order to reach consensus. Eliminate those



Modified Multi-Voting

Purpose

Modified multi-voting is a technique to help a team or group quickly reduce a large list of items to a smaller number of high priority items. The process often results in a high degree of team agreement and it promotes team ownership. This tool is similar to the nominal group technique but it is less involved.

1 = + 2 = 0 3 = & 4 = D 5 = •

Step 1

Count the number of items on the list and divide by three. This is the number of votes each person has. (Round fractions off to the lower number.) If the items number more than 60, use a total of 20 votes. More than 20 votes are difficult to manage. Each person has one symbol (see above) for each vote.

Step 2

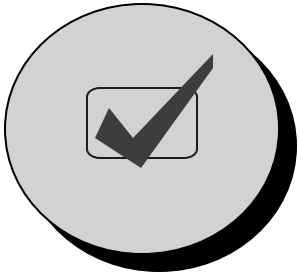
Each person should use their votes (or symbols) to select the items they want to keep. Each person can vote for any item. However, it is a good practice to limit the number of votes that any person can assign to one item to three; the team can decide if they want to increase or decrease this limit.

Step 3

List the alternatives in the new, prioritized order.

Step 4

Critically discuss the top alternatives in order to reach consensus. Eliminate those that are outside the control of the team.



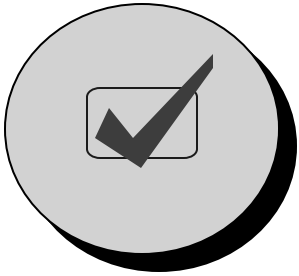
Prioritization Matrix

Purpose

To prioritize tasks, issues, alternatives, etc., to aid in selecting which tasks, issues, alternatives to pursue.

Steps

1. Generate a set of criteria to be used in establishing the quality of the decision.
2. Construct an L matrix with options, etc. down the left and selection criteria across the top.
3. Each person prioritizes the criteria by distributing the value 1.0 among the criteria (i.e., sum of weights is 1.0).
4. Sum the weights from each person for each criterion; the sum becomes the team's weight for the criterion. Enter these weights in the L matrix in brackets; each column will have the same number in each cell.
5. Examining one criterion at a time, rank (order) all the options, etc. with respect to the criterion using the modified nominal group technique. Enter the vote totals for each issue into the L matrix.
6. Find the product of the vote totals and weight for each issue and sum these products for each row.
7. The rows with the highest sums are the issues of highest priority. Be sure to discuss any row which has a low total but seems important enough to retain.



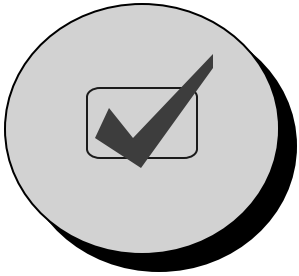
Criteria Prioritization Matrix

Purpose

To improve any decision making process by rationally prioritizing or ranking criteria (which will then be used to prioritize the tasks, issues, alternatives, etc.).

Steps

1. Generate a set of criteria to be used in making a 'quality' decision.
2. Construct an L matrix with criteria down the left side and criteria across the top.
3. Compare the criteria in EACH row with the criteria in EACH of the columns (i.e., a 'pairwise' comparison).
4. The Team should discuss each comparison and reach consensus on the relative importance of the two criteria. Avoid voting if at all possible.
5. Enter the appropriate word (e.g., =Same), or value, for the comparison in the appropriate ROW and COLUMN (e.g., R1 / C2).
6. Enter the RECIPROCAL of the word (e.g., =1/Same), or value, entered in 4. above in the corresponding COLUMN and ROW (e.g., R2 / C1).
7. Sum the numerical values in each row for each criterion. The sum becomes the team's weight for the criterion.
8. The rows with the highest sums are the criteria of highest priority. Be sure to discuss any row which has a low total but seems to be more important than the total indicates. Always review the numerical values to determine if they 'make sense' to the team!



Criteria Prioritization Matrix

(1) Compare the criteria in EACH **row** with the criteria in EACH of the **columns** (i.e., a 'pairwise' comparison)

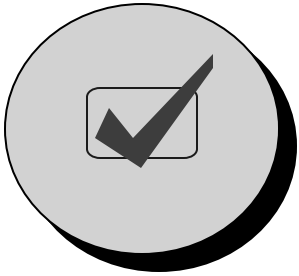
(2) Enter the appropriate **word** (e.g., **=Same**) for the comparison in the appropriate ROW and COLUMN.

For example, if Grades (**Row 1**) are Less Important than Learning (**Column 2**), then enter **=Less** in **R1/C2**.

(3) The HIGHER or LARGER the % , the MORE IMPORTANT the criteria.

=Much More Important	=More Important	The =Same	=Less Important	=MuchLess Important
9	3	1	0.333	0.111

Criteria		Grades	Learning	Mental	Physical	Relationship		
	X	1	2	3	4	5	Total	%
Grades	1	X	0.33	1.00	1.00	1.00	3.33	16
Learning	2	3.00	X	1.00	1.00	1.00	6.00	28
Mental	3	1.00	1.00	X	1.00	1.00	4.00	19
Physical	4	1.00	1.00	1.00	X	1.00	4.00	19
Relationship	5	1.00	1.00	1.00	1.00	X	4.00	19
		6.00	3.33	4.00	4.00	4.00	21.33	100
		28.1	15.6	18.8	18.8	18.8	100	21.33



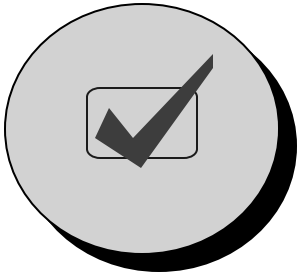
Task Prioritization Matrix

Purpose

To improve any decision making process by rationally prioritizing, or ranking, tasks, issues, alternatives, etc. using weighted criteria.

Steps

1. Generate a set of criteria to be used in making a quality decision. Determine the weight for each criterion using the Full Consensus Criteria Matrix process.
2. Construct an L matrix with tasks, etc. down the left side and the selection criteria across the top.
3. Enter the 'full analytical criteria' weights in the L matrix in the row below the criteria.
5. For EACH criteria (or column), rank order all the tasks, etc. with respect to that criteria (e.g., using the modified nominal group technique). Enter the rank, or vote totals, for each task, etc. into the L matrix in the appropriate column and row.
N.B. The higher the rank, or the larger the number, the more important the task.
6. Find the product of the individual rank, or vote totals, and criterion weight for each task (or row), etc. and sum these products for each row.
7. The rows with the highest sums are the issues of highest priority. Be sure to discuss any row which has a low total but seems important enough to retain. Always review the numerical values to determine if they 'make sense' to the team!



Task Prioritization Matrix

(1) Enter the criteria and the numerical weights for each criteria in the appropriate rows below.

(N.B. This example uses Full Consensus Criteria from the matrix above.)

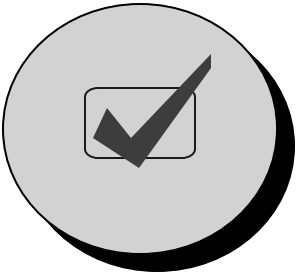
(2) Rank the **tasks** in EACH **row** using the criteria in EACH of the **columns**.

(N.B. The HIGHER the rank, or the LARGER the number, the MORE IMPORTANT the task.)

(For example, in the matrix below a rank of 5.0, or the highest value, is assigned to STUDY.)

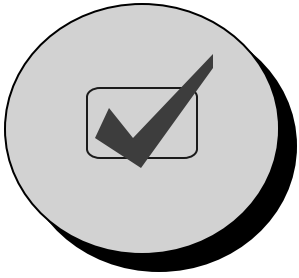
(3) The HIGHER or LARGER the %, the MORE IMPORTANT the **task**.

		Criteria	Grades	Learning	Mental	Physical	Relationship		
		Weights	0.156	0.281	0.188	0.188	0.188		
Tasks			1	2	3	4	5	Total	%
Attend Class	1		3.0	1.0	1.0	1.0	1.0	1.31	20
Homework	2		4.0	1.0	1.0	1.0	1.0	1.47	22
Recreation	3		1.0	1.0	1.0	1.0	1.0	1.00	15
Sleep	4		2.0	1.0	1.0	1.0	1.0	1.16	18
Study	5		5.0	1.0	1.0	1.0	1.0	1.63	25
			2.3	1.4	0.9	0.9	0.9	6.56	100
			35.7	21.4	14.3	14.3	14.3	100	6.56



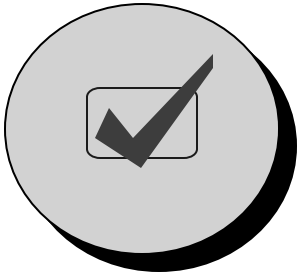
Process Check

- Monitoring of processes, especially processes which you own or are a part of, is necessary if improvement is desired.
- A process check is a formalized way to do this monitoring and should be used at the end of all process related activities.
- There are many different ways to conduct a process check.
- A process check must focus on the process.
- Failure of a process does not infer any judgment about the quality of the team members.

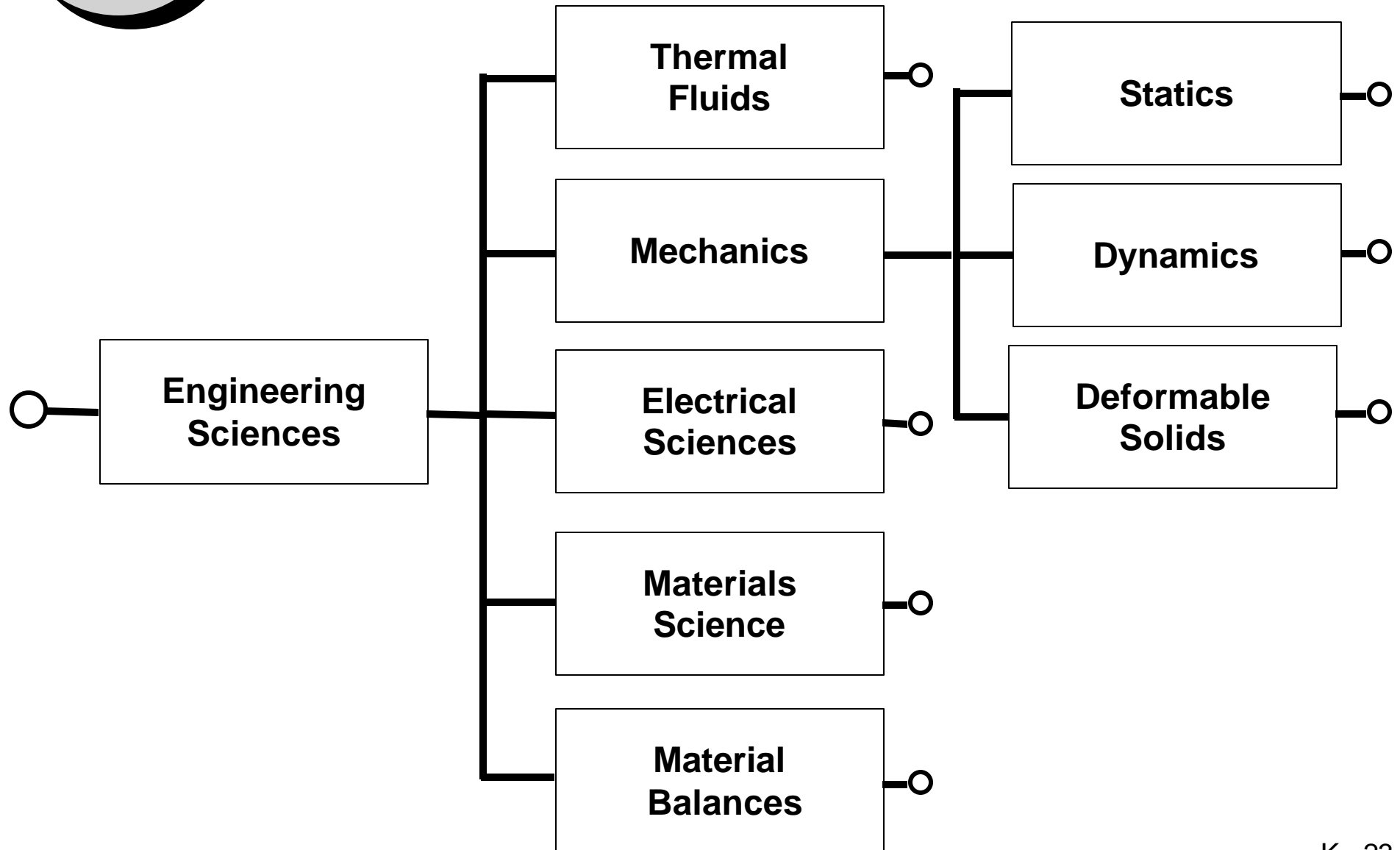


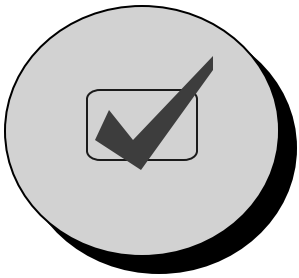
Tree Diagrams, Conventions

- Each item placed on the tree has, for example, a direct cause-and-effect relationship with the item to the left of it, i.e., the second level of detail directly causes the first level of detail to happen.
- Each level of detail, for example, answers the question, 'How will this be accomplished'?
- As you go from left to right, the level of detail gets finer.
- If the items at the lowest level of detail are 'recognizable' modules that can be implemented (e.g., can be assigned to someone else to accomplish), the tree is complete.
- Ask the following questions, for example:
 - Going from right to left: 'Will these actions really accomplish the next higher level of the task?'
 - Going from left to right: 'If I want to accomplish this, do I really need to do all of these lower levels of detail?'

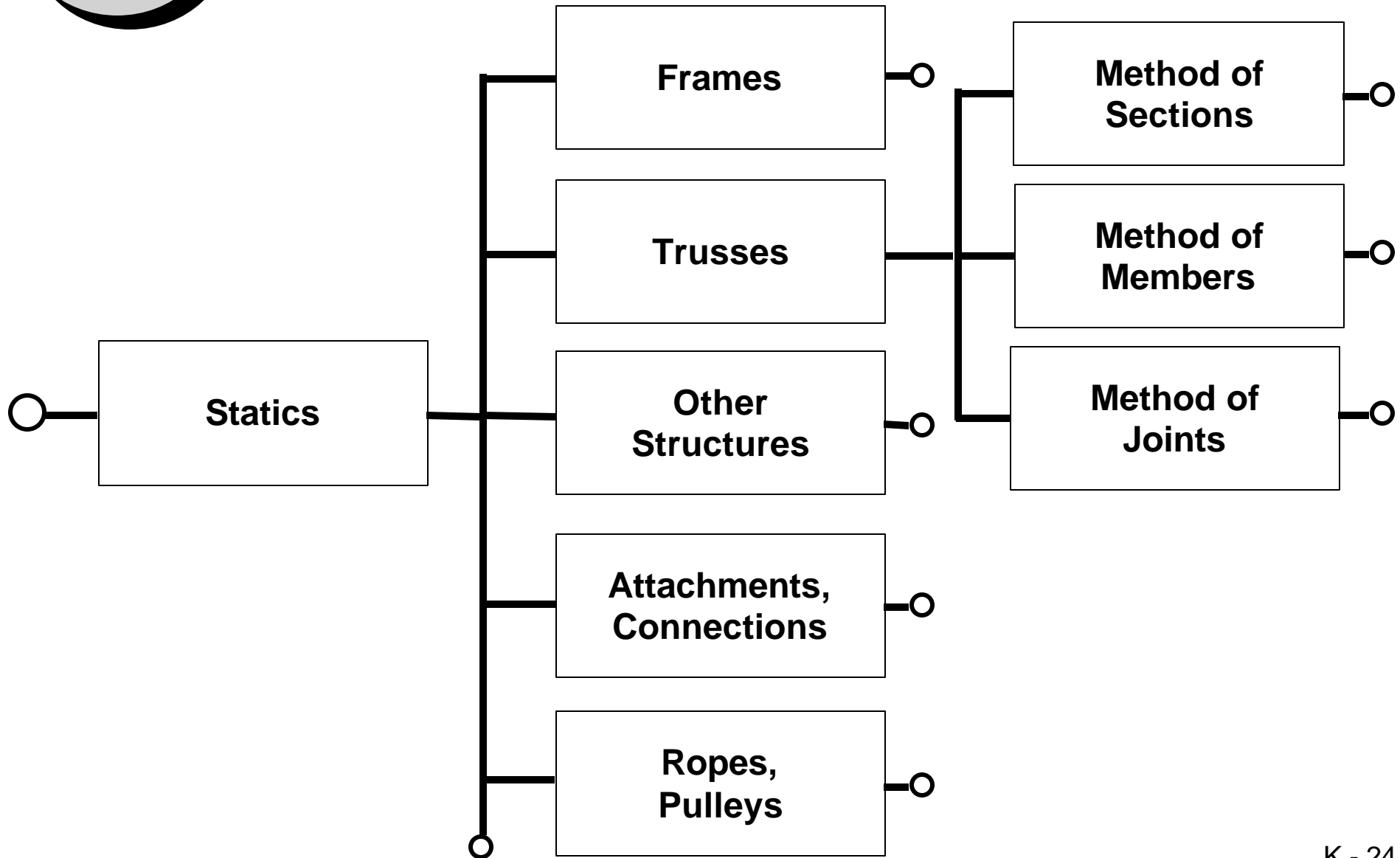


Tree Diagrams, An Example





Tree Diagrams, An Example (cont.)



SECTION L

ECE 100 *Modeling* Assignment # 1

Introduction to the Excel 7.0

Spreadsheet Program

The first work product required in the Modeling session of ECE 100 is an Excel 7.0 model. This section contains the instructions for preparing this work product. This section also contains information about Excel which will be useful in preparing all Modeling Assignments.

ECE 100 Modeling Assignment Introduction to Excel 97

Overview

This assignment is intended to provide an **introduction** to developing mathematical models using a spreadsheet. The instructions will guide you through the **process** of creating a model, solving the model, and displaying the results using charts and tables. After completing this assignment, you should have a sense of the power and flexibility of a spreadsheet program (like Excel) and be able to create your own spreadsheets. Only the most basic spreadsheet commands/operations are used in this assignment. Most of the operations illustrated can be accomplished by using alternate, or short cut, methods and you will no doubt use these other methods as you become more familiar with spreadsheets. This assignment can be **supplemented** with the **on-line tutorial** available on ECE 100's Web page as well as by using the **Help** function in Excel.

Reflection is an important process in learning. Based on the experience of prior students, you should pause at the end of **each part** of any given assignment to make notes on the important points of the tasks or operations you have just completed (i.e., what do you think was important?). After completing your 'reflections,' you might also want to try to perform the operations/tasks that you have just completed **without looking** at this document. These practices are encouraged in ECE 100 in order for students to become **life-long learners**.

Suggestions for Using Other Versions of Excel

You will be using the Computing Services facilities in Computing Commons or Goldwater Center which support Excel 97. If you are using an **earlier version** of Excel at home (e.g., Excel 6.0, Excel 95), you can save your files on campus as an earlier version. To do this, select **File** on the menu bar, then pull down to **Save As**. A pop up window will appear. In the box below **Save File as Type:** you can select the version of Excel you have at home. Note that in coming from home to school (i.e., from an earlier version to the more recent version), you don't have to do anything special. The newest versions of programs will read all the older ones, but not vice versa.

ECE 100 Modeling Assignment Introduction to Excel 97






Notes on the Computing Environment

This assignment is primarily intended to help you learn to use the Excel program which will be used in Modeling; it does not address accessing the micro-computer network on campus. Micro-computer network documentation is available, on-line, at the time you log onto the system. To get this help, double-click the **Applications** folder on the **Desktop**, then double-click the **Help** folder and a number of Help items will appear. You will then need to select the topics of interest to you. You may also want to go to **COMPASS** on the second floor in Computing Commons to obtain written documentation on the network as well as other software and utilities you may be using in Computing Commons. COMPASS also has manuals for Windows, Excel, and other application programs.

Excel 97 is a **Windows** program; it is compatible with other Windows programs (e.g., Word) and is used in the Windows environment. This document does not provide Windows instructions. It is highly recommended that you familiarize yourself with Windows. This familiarity will help you use Excel as well as any other Windows compatible software you may find useful in this and other courses.

Getting Started: Mouse Tips

The ASU personal computers are all equipped with a 'mouse.' You should familiarize yourself with its use, particularly in Excel since the shape of the mouse pointer in Excel changes for different actions. The following mouse 'pointer' symbols should be recognized:

- The thick white cross  will appear as you move around the cells of the document window.
- The black cross hair  called the fill handle, appears when you bring the pointer to the little square on the lower-right corner of the current cell. It is generally used during copying and sizing operations.
- The thick white arrowhead  is the pointer used on the toolbars, menu bars, and control boxes along the edges of the window.
- The I-beam  is used in editing operations.
- The hour glass  symbol tells you that the program is working; wait for the next prompt.

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If you have a right button on your mouse, it can also be very useful for Excel operations. Click the right hand button once and a pull-down menu of the possible Excel operations will appear (Note: on the Mac, hold down **Option** and **Command** and click the mouse button once). Using the right hand button for this purpose minimizes the need to use the menu bar. The use of this and other short cuts can substantially reduce the time required to develop an Excel spreadsheet model.

Getting Started: Display Screen

When you log on using one of the PC's on campus, the desktop screen will appear. Move the mouse pointer (the arrow) to the **Start** button in the lower left corner of the screen. Click the left mouse button, then click **Programs**, then **Spreadsheets**, then **Excel**, and finally **Excel 97**. Following the Excel title screen, the following screen will appear:

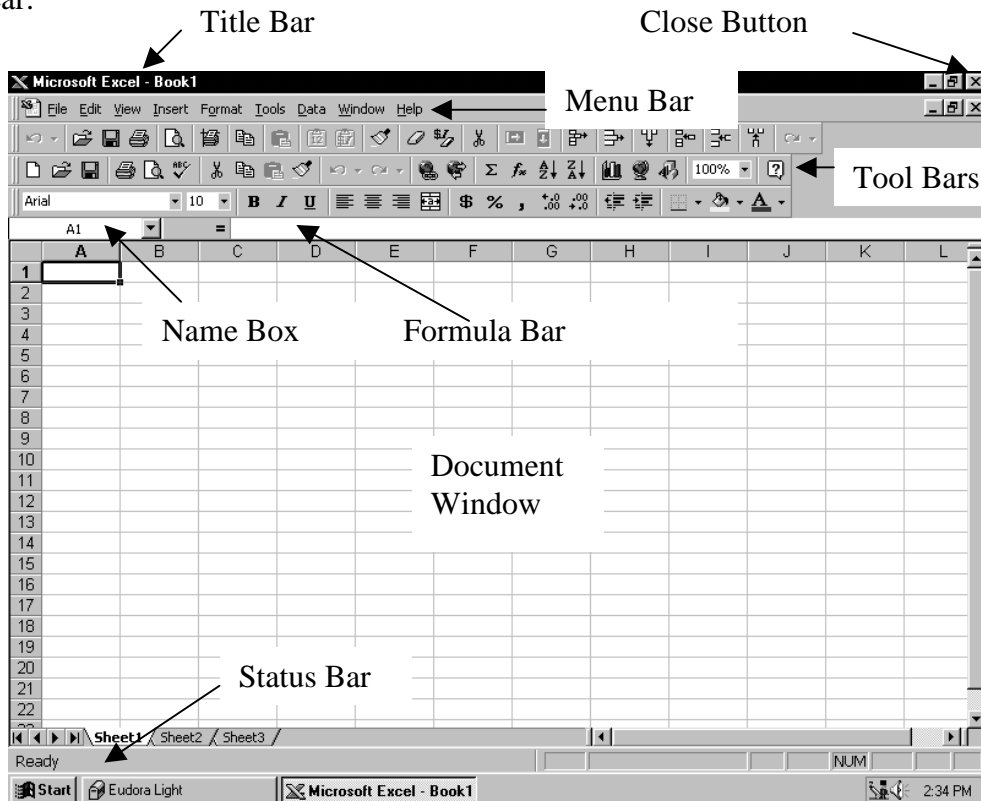


Figure 1

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Note the following key parts of the Excel program window (as illustrated in Figure 1):

- **Title Bar** – the top most bar on the Excel window; it shows the name of the program that is currently running
- **Close Button** – the X in the upper right hand corner; it is used at the end of the session to close the file (bottom X) or the program (top X)
- **Menu Bar** – lists the main Excel pull-down menus; these menus allow you to select from a variety of commands used in Excel
- **Tool Bars** – short cut methods for various commands; if you point the mouse at these boxes, a highlighted box will appear which describes the function of the box
- **Name Box** – displays the address or name of the current cell
- **Formula Bar** – displays the contents of the current cell; it shows the text, data, or formula that has been entered in the current cell
- **Document Window** – this area is divided into cells where relevant information is entered; the cells are addressed by a column letter and row number (i.e., B5); the column letters are shown along the top of the document window and the row numbers are along the left hand side of the window
- **Status Bar** – displays information about the current status of Excel and may include messages relating to the activity that you have chosen to perform; the right hand portion indicates some of the settings of the keyboard (i.e., Caps Lock...)

In addition, the Excel window has some standard Windows control buttons/bars: Scroll Bars, Scroll Arrows, Minimize Button, Size Box. You should become familiar with these control features by studying Windows (you can select **Help** from the **Start** button and execute the **Windows Tour** to get an introduction).

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Getting Started: Spreadsheet Document Window

As mentioned above, the Excel Document Window is divided into columns and rows. The cell is a box on the document window and can contain information: text, data, or equations (formulas). The coordinated use of this information constitutes the spreadsheet application. An Excel sheet can contain 256 columns and 16,384 rows, extending well beyond the boundaries of the monitor screen. A document may contain extra **sheets** to provide a large three-dimensional domain. These other **sheets** can be accessed by clicking on the labeled tabs at the bottom of the document window.

Getting Started: Cell Selection

When you start Excel, the **A1** cell is automatically selected as the current cell (see Figure 1). This cell is highlighted, meaning it is ready to receive input from you. You can change the current cell by moving the mouse's pointer to any desired cell and clicking the mouse. The new current cell will be highlighted and the address or name of the new current cell will appear in the **Name Box**.

Getting Started: Entering Text

Three types of information can be entered into the Excel cell: **text**, **data**, and **formulas**. Excel will automatically interpret what you type and select the appropriate category for the information. For example, if what you type begins with a letter of the alphabet, it **automatically** becomes **Text**. Alternatively, if the information begins with an **equals sign** (=), Excel **automatically** assumes that the information is a **formula**.

Text material is entered directly by typing the information through the keyboard. **Text** is normally '**left justified**' in Excel; it is displayed in the left-hand portion of the cell. If you wish to specify that certain information within a formula is text, you should put single quotation marks around it.

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If the information is data, it usually consists of numerical values and Excel will treat it as such. Excel **data** is '**right justified**' in Excel; it is displayed in the right-hand portion of the cell. This convention can help you distinguish between text and data easily.

As mentioned above, formulas start with an equals sign and are a convenient way of calculating tables of values. We will show you how to enter formulas explicitly later.

As you type the information, it will appear in the current cell and also in the **Formula Bar**. When the information is completely typed, press Enter.

EXCEL MODELING ASSIGNMENT (to be handed in)

Entering a Descriptive Title, Your Name, and Your Team Number

For every assignment, you must enter your name and team number in your spreadsheet. Select the cell **F1** as the current cell, then type the following and press **enter**:

Your Name : Your Team Number

The standards for organizing and presenting technical work require that every spreadsheet contain a descriptive title. Select cell **A1**, then type the following and press **enter**:

NASA Cone Design problem

Note the lower case 'p' in the word problem. Notice that the title you just entered overflows into cells **B1** and **C1**; this should not present a problem unless you wish to enter some other information into these cells.

Editing the Descriptive Title (Editing Text)

Text that has been entered into a cell may need to be corrected or erased. The simplest way to correct the entry, if the text is not lengthy or complicated, is to retype it. To do this, select the cell you wish to edit. The old text will appear in the **Formula Bar**. Typing will overwrite the old text.

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Another way to edit text is to make correction on the **Formula Bar**. Select the cell in question. Move the mouse's pointer to the point in the text in the **Formula Bar** where you wish to edit (the cursor symbol will turn into the I-beam). We want to capitalize the 'p' in problem. Select cell **A1** as the current cell (even though the word 'problem' appears in cells **B1** and **C1**, remember that **A1** is where you entered the title). Move the pointer to the **Formula Bar** just before the letter 'p' and click the mouse (the I-beam should appear in front it). Hit the **Delete** button and the letter 'p' is erased. Now type a capital letter 'p.' While here, notice that you can move the I-beam to the left or right by pressing the appropriate **arrow keys**. This can make editing easier when you have multiple errors to fix. Press **Enter** to keep your changes to the title.

To delete text from a cell, select that cell as the current cell. Go to the **Menu Bar** at the top of the screen and select the **Edit** menu. A pull-down menu will appear. Holding the left mouse button down, move the cursor down to the entry **Clear**, the pull-down menu should like the figure below. If you move the pointer to the selection **All**, all of the contains of the selected cell will be removed.

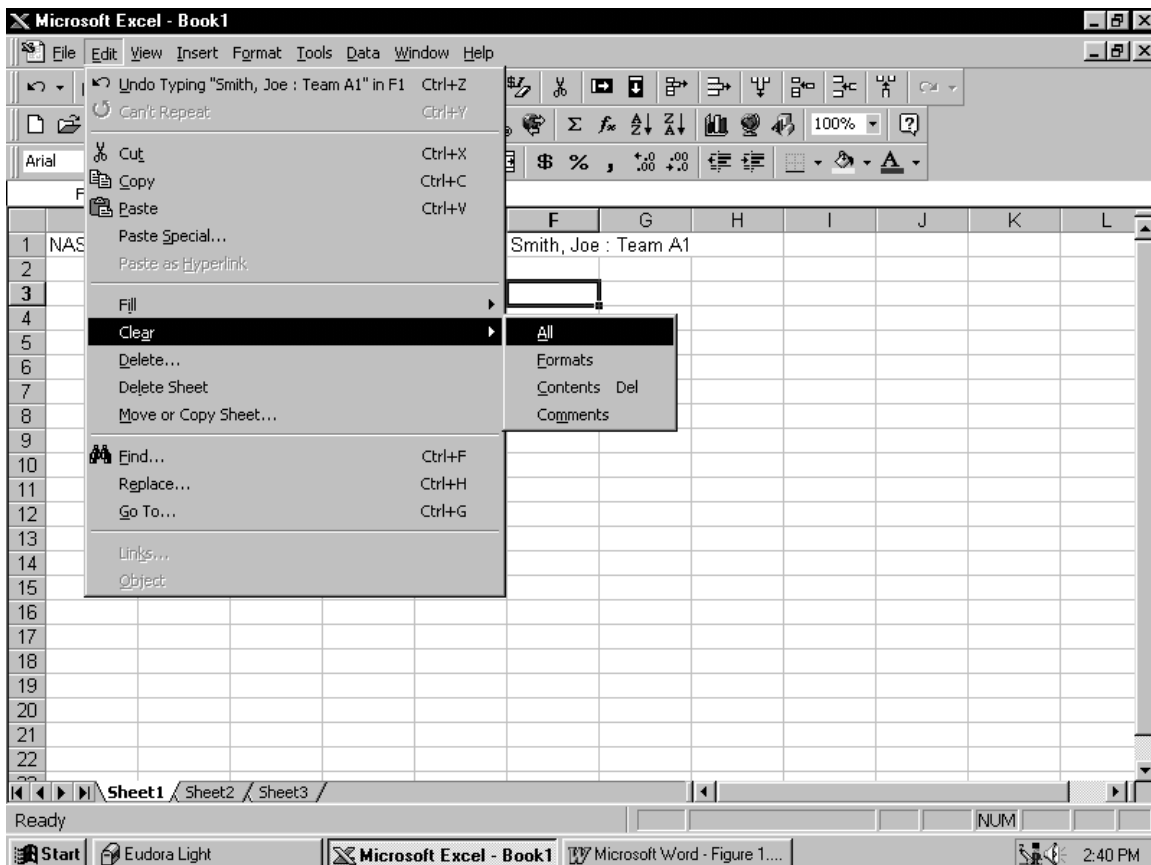


Figure 2

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The 'Data Entry' Area, Entering & Labeling the Model Variables (including units)

The data used in a model are often referred to as 'variables,' 'design variables,' or 'parameters' and must be presented in a data entry area or section of the spreadsheet (see Section J, Part I). The process for constructing this data entry area is presented below.

Re-enter the title into cell **A1** if you erased it in the previous exercise. Select cell **A4** as the current cell. Type the word **Design** and press enter (the current cell is now **A5**). Enter the word **Variables**. In cell **A7**, type **Height (cm)** and in cell **A8**, type **Radius (cm)**. Your worksheet should look like Figure 3 below.

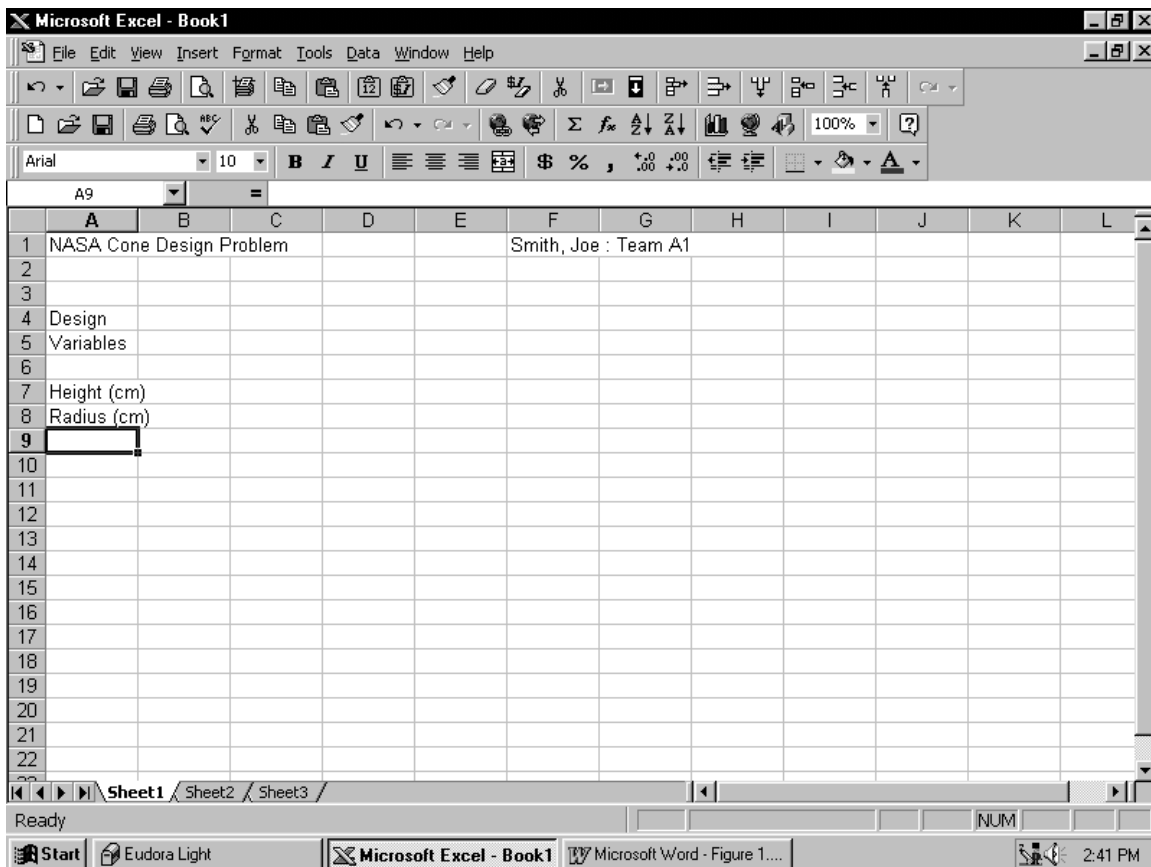


Figure 3

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Formatting Cells

You can see that the last two entries overflow their respective cells into column B since the text is longer than the original 8.43 ‘**standard characters**’ allocated by Excel for each cell. We are going to enter information into cells **B7** and **B8**. The overflow text would not be visible if we did not enlarge the cells so the entire text would fit within them. We are going to enlarge the entire Column A.

Since we want to adjust the cell widths to fit the contents of cells **A7** and **A8**, select cell **A7** as the current cell. Move the pointer to the **Menu Bar** and point it to the word **Format** and click the mouse. A pull-down menu will appear. Since you want to enlarge Column A, move the pointer down to **Column** and click the mouse once. An options menu will appear. We want Excel to decide how wide the cell should be, so move the pointer to **AutoFit Selection** (see Figure 4) and click the mouse once. If you have a specific width in mind you could have selected **Width** and entered the size.

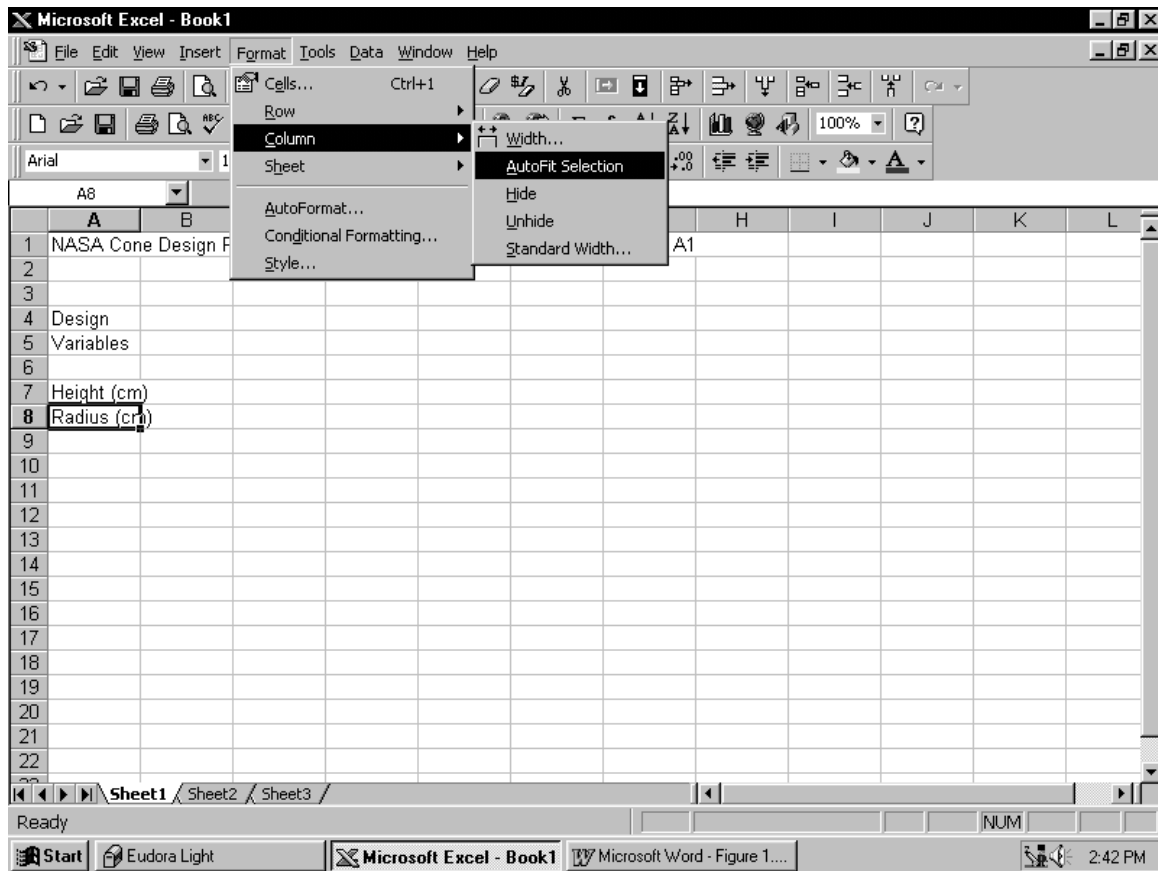


Figure 4

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Your window should look like Figure 5. Note that the text in cell **A1** is still overflowing into the adjacent cells. Since we're not going to enter any information there, it doesn't matter.

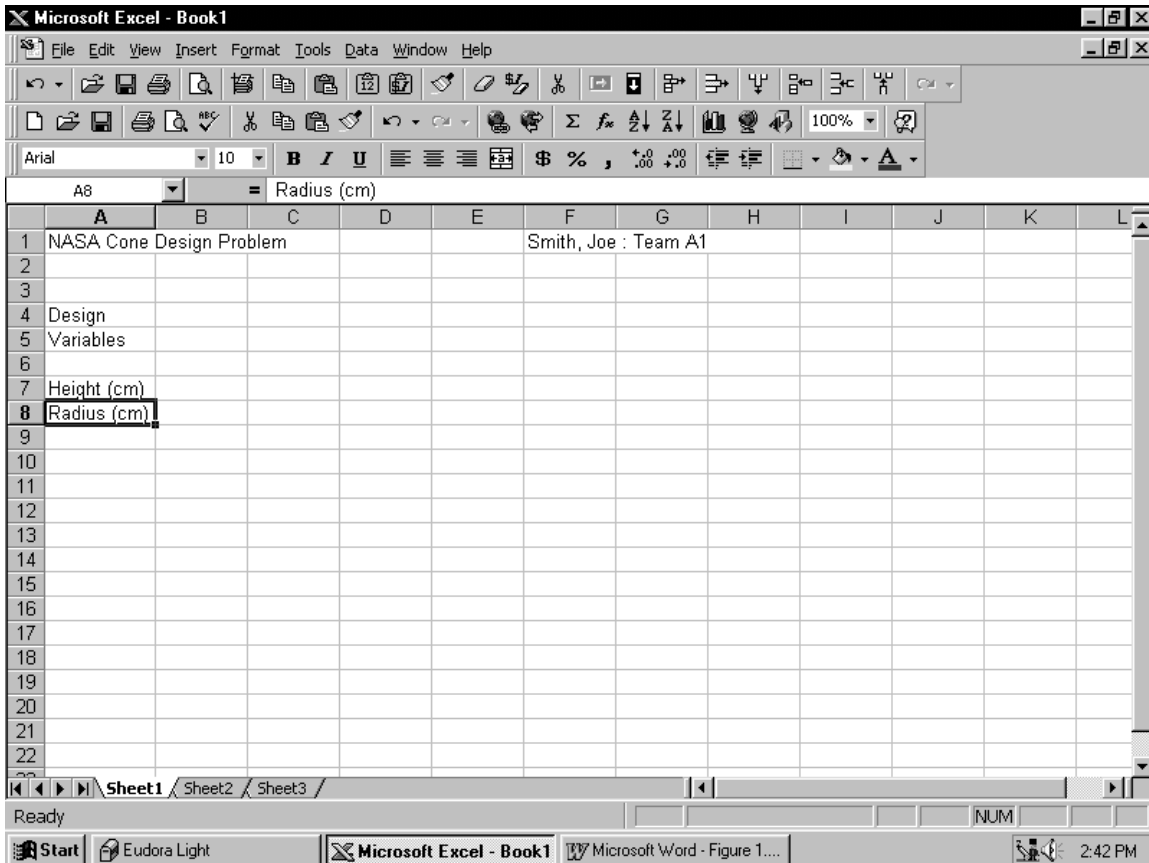


Figure 5

The 'Calculation' Area, Constructing & Labeling the Model

The calculations that are required for the model must be organized and presented in a section or area that is separate and distinct from the data entry area. Select cell **F3** and enter the word **Cone**. In cell **F4**, enter the word **Radius** and in cell **G4**, enter the word **Volume**. To indicate the appropriate units, in cell **F5** enter **(cm)** and in cell **G5** enter **(cc)**.

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Copying Text

There is a shortcut method for copying text into adjacent cells. We want the word **Cone** to appear in cell **G3**. To do this, select cell **F3**. Then, bring the pointer to the bottom right corner of the cell (there is a little black square in the highlighting there). The pointer will change to a **black cross** when you are in the right spot. Hold down the mouse button (make sure the **fill handle** remains) and drag the mouse across to cell **G3**. As you move the pointer into the new cell area, a fuzzy grayish highlight appears around the cell and the cell area is highlighted. Let go of the mouse button and the contents of cell **F3** are copied into **G3** (see Figure 6). Note that you can copy the text into more than one cell by continuing to drag the **fill handle** across. You can only copy in one direction. If you want to copy into a second direction (down, for example), you must repeat the process.

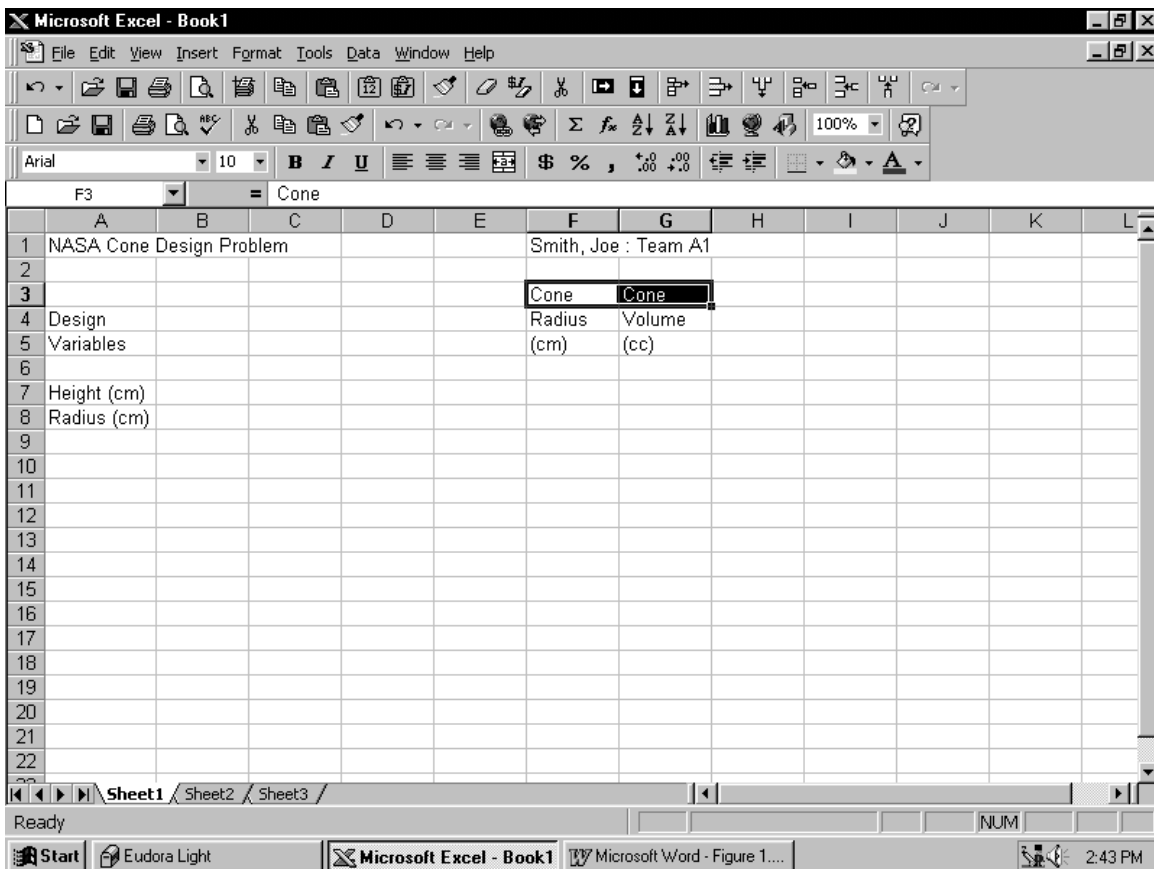


Figure 6

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Entering Data

You must organize your spreadsheet in such a manner that it be easily read and understood by others. On the left-hand side of your spreadsheet, you prepared a data entry section. Here you can enter the input data (or constants) you will need in your calculations and can readily see the initial conditions. Furthermore, should you want to use these input data in more than one equation, you can refer to them using their cell addresses rather than rewriting the data every time. Also, should you wish to change one of these values, you only have to change it once in the data entry section instead of in every equation or formula in which it was used.

Select cell **B7** and enter the number **20** (notice that the data is right justified). In cell **B8**, enter the number **5**.

Entering Formulas (in the 'Calculation' area of the Model)

You prepared the headings for a table which will include the results on the right hand side of the spreadsheet (columns F and G). This area is called the 'calculation' area of your model. You will eventually want to evaluate cone volumes for several values of the radius; thus, you will want to tabulate your results. As the first entry in the table, select the value of the radius you entered in the data entry section (cell **B8**). You can enter the radius value into cell **F7** by typing 5, or you can equate the table entry **F7** with the original input data entry **B8** by entering the formula:

=B8

which is equivalent to saying that the content of cell **F7** equals the content of cell **B8**.

To accomplish this, select cell **F7** as the current cell and you can type =B8 and press **Enter**, or you can type = and then click on cell **B8** and =B8 will appear in the **Formula Bar** and then press **Enter**.

When you enter this formula, the numerical value 5 will appear in cell **F7**. Experiment a bit, enter a different value into cell **B8** and see how the value in **F7** changes automatically. Note that when cell **F7** is the current cell, the **Formula Bar** displays the formula while the cell **F7** displays the value 5 (or whatever is in **B8**). Now make sure cell **B8** has a value of 5 in it.

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Now enter the formula to evaluate the cone volume into cell **G7**. Select **G7** as the current cell and type

$= (1/3) * \text{pi}() * \text{B7} * \text{F7}^2$ and press Enter

The function **pi()** represents the commonly used geometric values of 3.14... (More about functions later). In your formula you need the cone height, a value you previously entered into cell **B7**, and the square of the radius, **F7^2** (the **carrot** (^) notation represents raising to a power; i.e., in our formula we're raising the contents of **F7** to the second power). The value 523.5988 should appear in cell **G7** (see Figure 7).

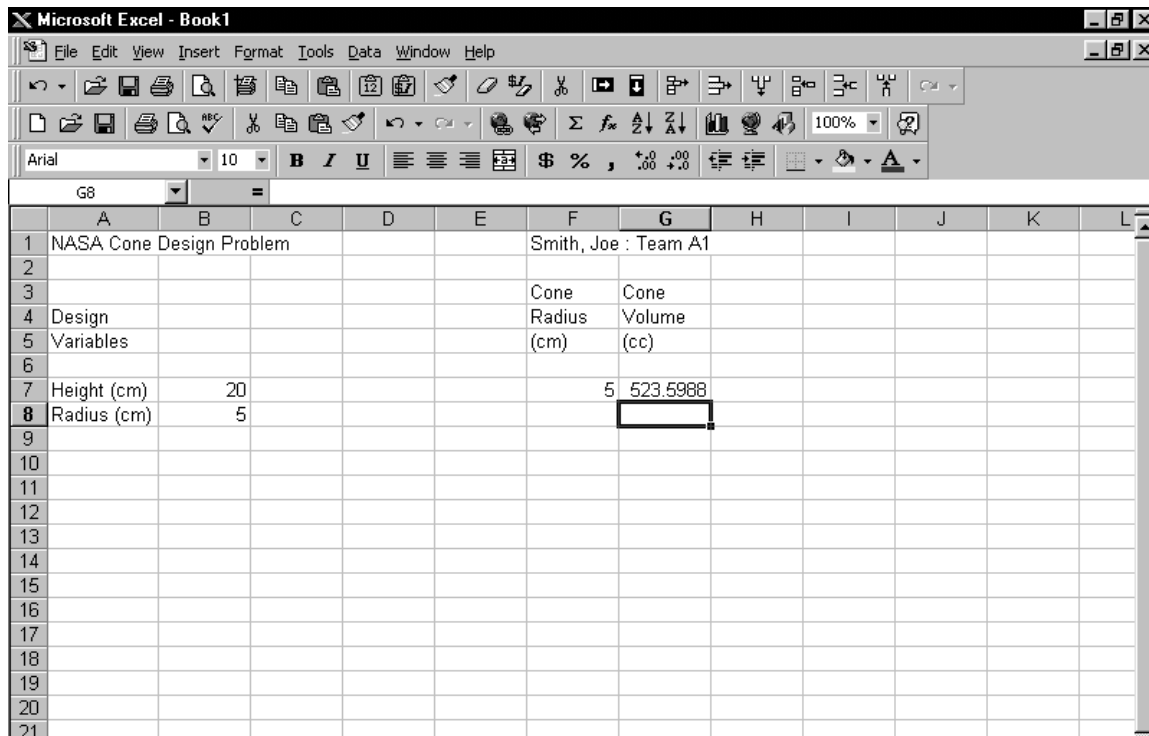


Figure 7

Saving Programs

You will want to save your model for future editing or use. If you are working on a lengthy problem or project, it is sound practice to periodically save your work. You should save your work on your **M drive** at school as well as onto a **diskette**.

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To save your program onto a diskette, you should have a formatted diskette available; place this diskette into drive **a:**. Move the pointer to **File** on the **Menu Bar** and holding down the left mouse button, pull down to **Save** and let up on the mouse button. The following dialogue box will appear (see Figure 8). Note: you can also get to the same pop up window by clicking the box that looks like a diskette on the **Toolbar**. Click on the arrow on the **Save in:** bar and then click on **3 ½ Floppy (A:)**; this will change the saving path to the diskette you've inserted. Click on the **File Name** bar and type **Cone.xls** and then press **Enter**.

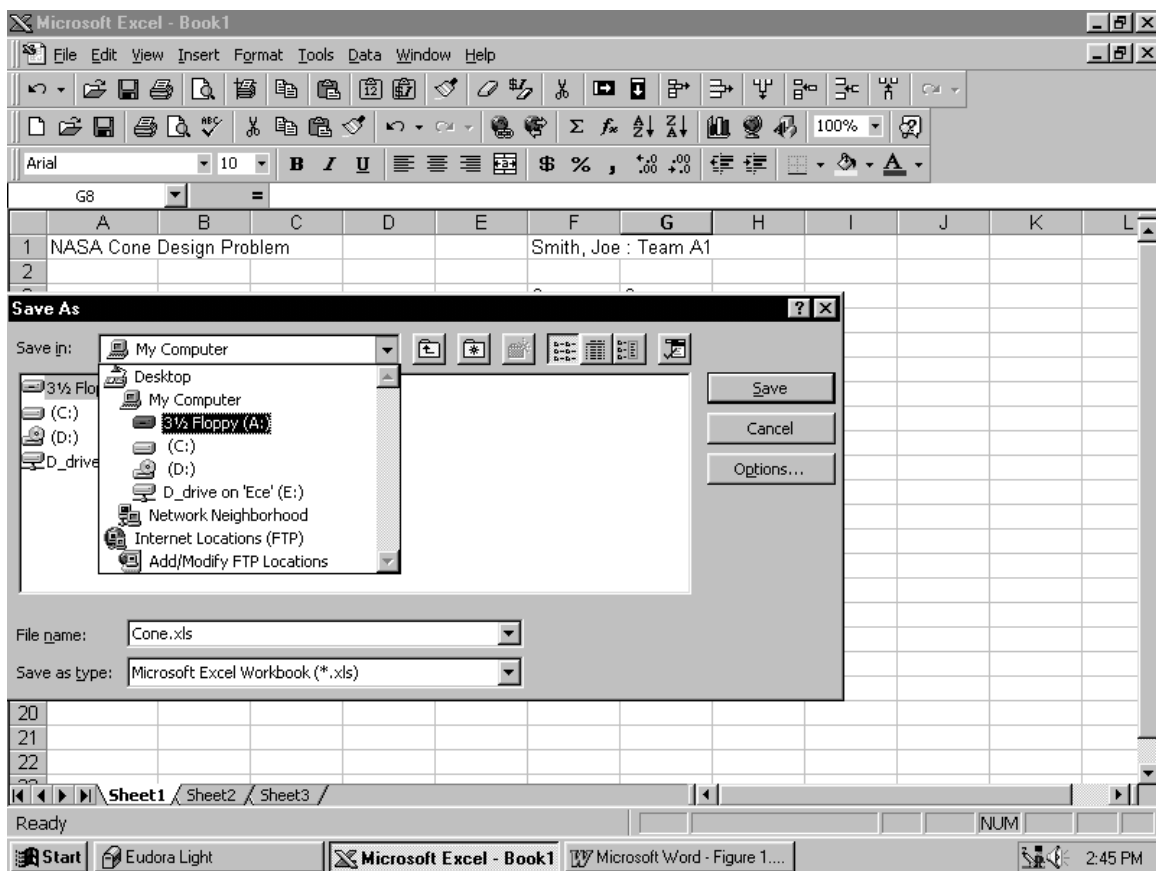


Figure 8

Now you may quit your session by exiting Excel by clicking on the **Close Button** on each screen. To terminate your Windows session, from the **Start** button, choose **Shut Down**. Be sure to remove your disk from the disk drive and label it.

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Restart the Program

Should you wish to continue your work on a previously saved program, enter Excel via the **Start** button menu then click on **File** on the **Menu Bar**. On the pull-down menu, select **Open**. This will bring up the dialog box shown below (see Figure 9). Click on the arrow on the **Look in:** bar and then click on **3 ½ Floppy (A:)**. The files on your diskette will be displayed. Double click on the file name you wish to open. Your spreadsheet will appear on the screen.

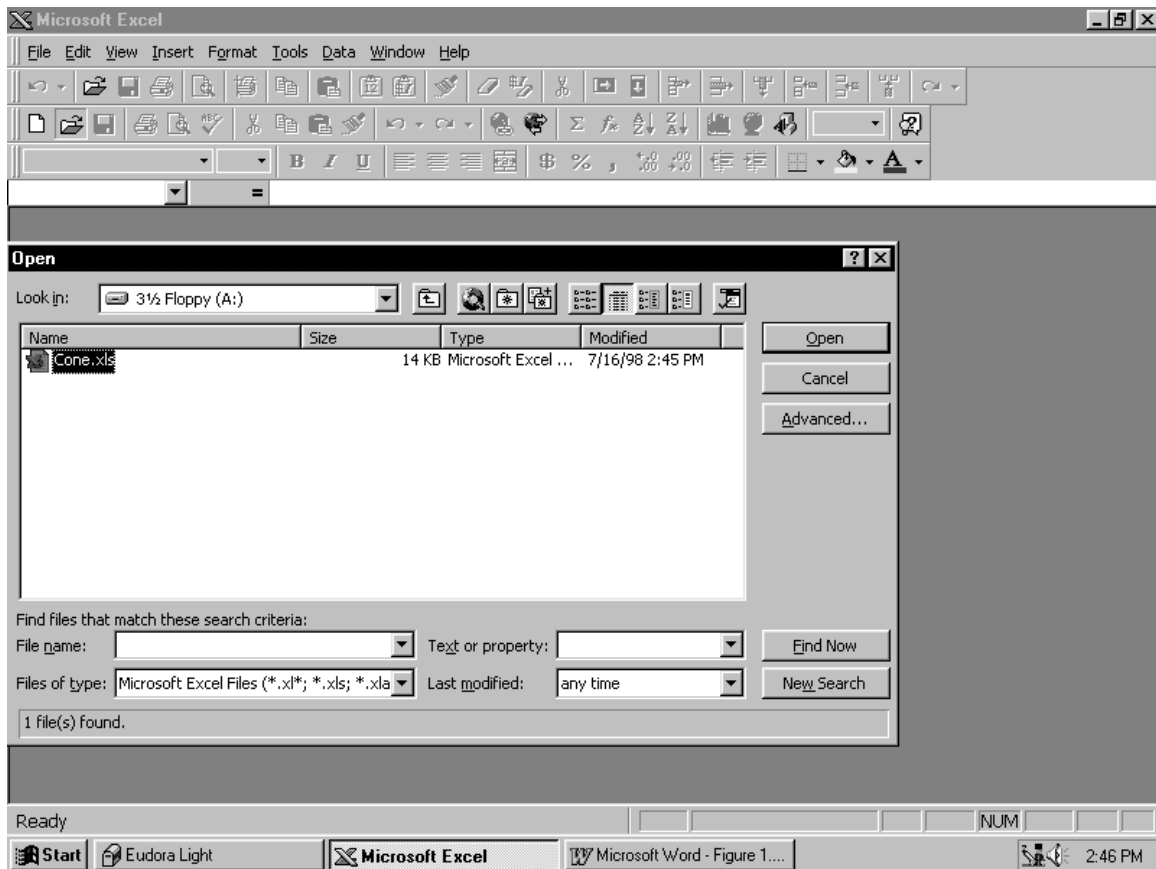


Figure 9

Building a Table

You are now ready to build a table which shows how the cone volume varies with base radius at a fixed value of the cone height. The cone height is referred to as a model **parameter** while the base radius of the cone is referred to as the **design variable** in this exercise. A table should be as flexible as possible, so that it will be easy to change the values of the design variable and to plot the data.

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You already have an initial value of the radius (entered in cell **B8**) which is automatically transferred into cell **F7**, the first cell of our table. You could manually enter other values of the radius into the table, but there is an easier method since we are going to increment the radius by a constant value. First we need to define the increment value in the input data section of our spreadsheet. Select cell **A9** and enter **Radius Inc.**. Then select cell **B9** and enter the number **2**.

We are now going to use a formula to increment the cone radius. Select cell **F8** and enter the formula: **=F7+B9**. If you select cell **F8** again, the formula can be seen on the **Formula Bar** and the value (i.e., **7**) can be seen in the cell (see Figure 10).

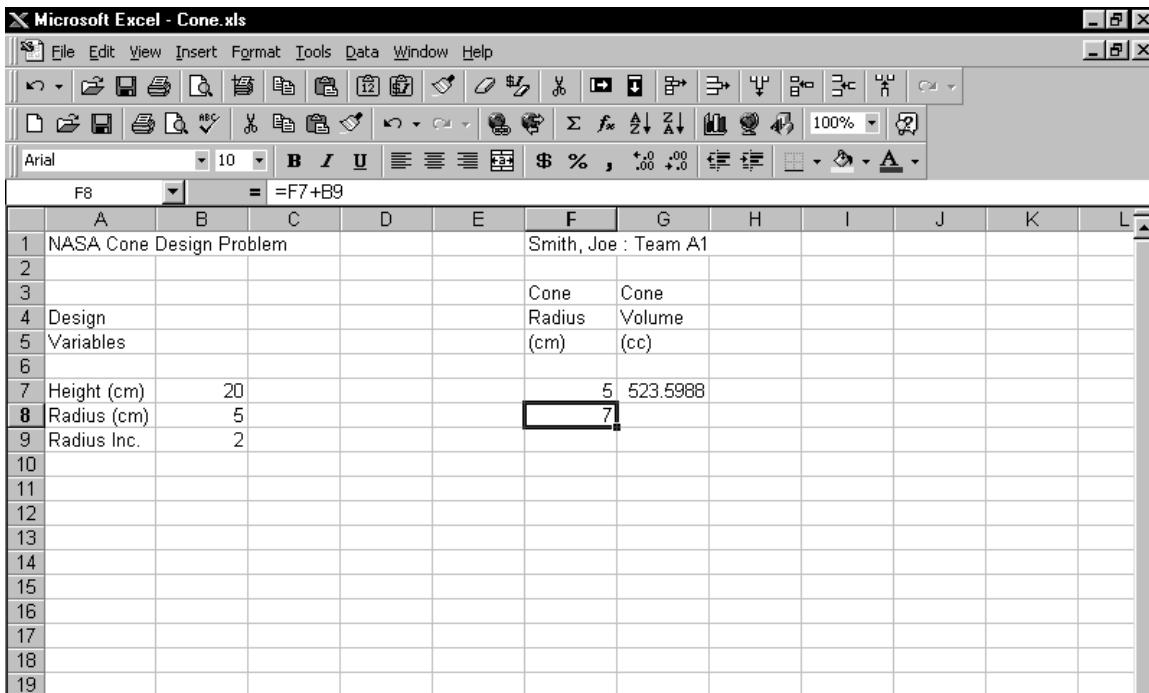


Figure 10

This formula could now be repeated down the line of the table. It would be rather tedious to re-type the equation eight more times, so we're going to use Excel's formula copying feature.

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Entering Relative and Absolute Addresses

It is now necessary to introduce the concept of relative and absolute addresses in a spreadsheet. **Absolute addresses** are used for data in general and for design variables or parameters in particular. We don't want to copy the formula in cell **F8** exactly or we'd get the value **7** over and over again. What we want is to copy a formula that says, "This cell equals the cell above plus the increment." So, we want the first cell address in the equation (**F7**) to change, but the second cell address to remain the same (**B9**). Excel's formula copying feature has an updating capability which will enter the appropriate formula into the cells below. This is the **relative address** feature of Excel.

There is a slight complication. Excel updates all relative addresses and not just the one we are interested. This means that if we copied the formula to cell **F9**, it would read: **=F8+B10**. To make the increment address fixed, we need to assign it an absolute address in the formula.

Absolute addresses are defined by the use of a dollar sign preceding the address. To specify the absolute column, you would put \$ in front of the letter B. To specify the absolute row, you would put \$ in front of the number 9. To make the cell absolute, you would type **\$B\$9**. To update your spreadsheet, select cell **F8** and edit the formula to read: **=F7+\$B\$9**.

Alternatively, you can give cell **B9** a name and the name will always be an absolute address. To name a cell, select cell **B9**. Then click in the **Name Box** on the **Formula Bar** and type **Increment**, then press **Enter**. You could now edit your formula to read: **=F7+Increment**.

In the copying process, the absolute addresses are copied exactly as you entered them and all other cell addresses are updated to relative addresses.

Copying Formulas

Copying formulas is similar to copying text. To copy the formula in cell **F8** into cells **F9** through **F16**, select cell **F8** as the current cell and then place the pointer at the lower right corner of the cell where it turns into the **fill handle**. Press down on the mouse and drag the fill handle down to cell **F16**. Just like when you copied text, the cell areas are highlighted in black and the region of cells are surrounded with the fuzzy gray border.

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When you release the mouse button, the correctly calculated radius values will appear in the cells. You should now have a column of numbers **5, 7, 9...23**. You may wish to experiment and see what happens to the values in the table as you change the initial cell radius, **B8**, or the increment, **B9**. If you do, make sure you change back to the original values before moving on.

Completing the Table

You next want to copy the volume formula into cells **G8** through **G16** to have the cone volumes associated with the various radius values. Before you copy the formula in cell **G7**, a small correction must be made to make the cone height an absolute address. There is a short-cut method for doing this instead of typing in the dollar signs.

Select cell **G7** as the current cell. Bring the pointer to the formula bar and click the mouse. Using the directional arrows, move the **I-beam** so that it is between the **B** and **7** in **B7**. Press the **F4 function key** at the top of your keyboard. This will automatically change the relative address **B7** into the absolute address **\$B\$7**. (Repeated pressing of the **F4 function key** deletes or enters dollar signs to give all the possible combinations of absolute and relative addresses). After editing the formula, press **Enter**. Your spreadsheet should now look like Figure 11 below.

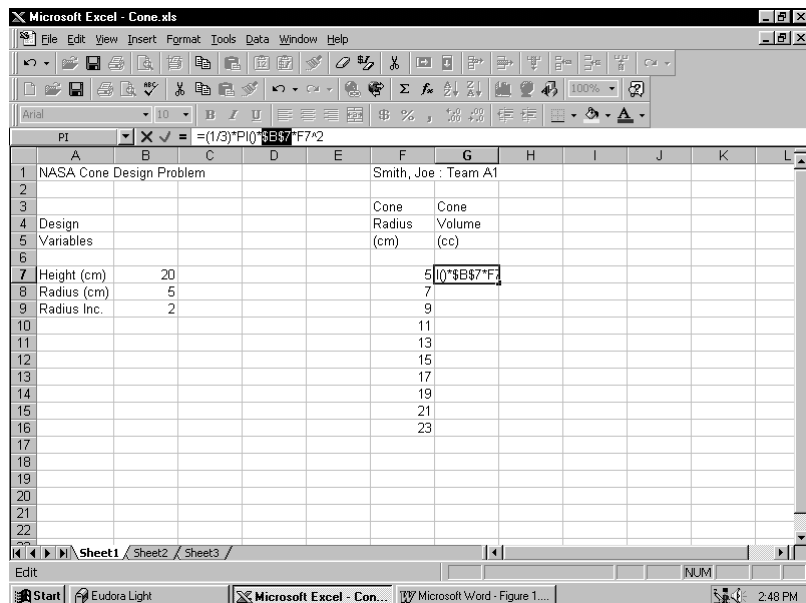


Figure 11

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Now with the **G7** as the selected cell, copy the formula into cells **G8** through **G16** just like you did above. When you release the mouse button, your table should look like Figure 12 below.

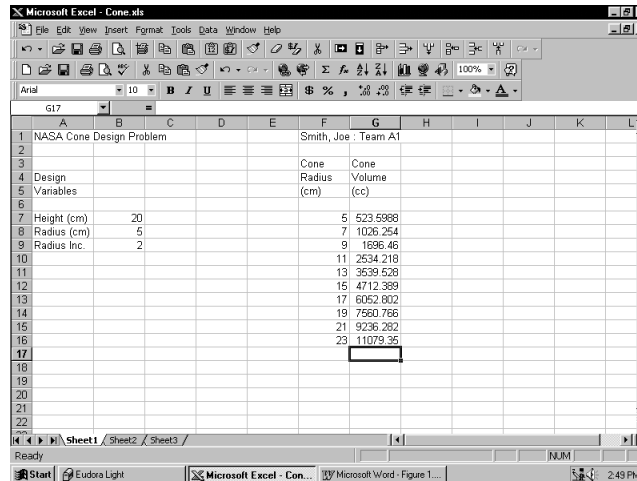


Figure 12

You will now want to consider the number of significant digits that you want displayed on your spreadsheet. For example, when decimal digits are not appropriate for your application, you should reduce the number to an integer. Mark the cells you wish to change (**G7** to **G16**) and click on the **decrease decimal button** on the **Tool Bar** and continue pressing this button until the numbers are integers (see Figure 13). Note: the actual value of the number does not change, only the number that is displayed.

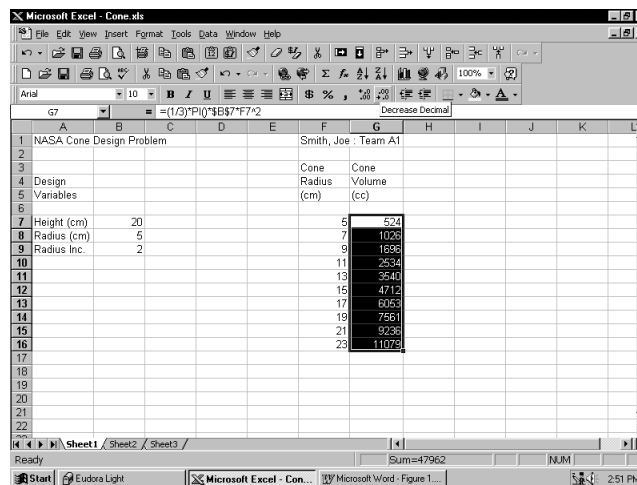


Figure 13

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You can also change the format of your cells. If you go to **Format** on the **Menu Bar** and then select **Cells**, a pop up window appears in which you can change the Alignment, add Borders...

Creating a Chart

The next task is the creation of a chart using the data in the table you have just created. The chart should display the cone volume versus the cone radius. Excel has the capability of creating Bar charts, Line charts, Pie charts, Area charts, XY(Scatter) charts, and others. In addition, Excel provides numerous options and variations of these visual presentations. In this exercise, you will create a **XY(Scatter)** chart.

You will use **Chart Wizard** to create your chart. It is depicted by a Bar chart on the **Tool Bar**. Chart generation follows a sequence of Excel controlled steps. However, at each step, there are choices for the user. You will create an embedded chart, a chart located on the same worksheet as your spreadsheet, by following the steps detailed below.

First: Move the pointer to the **Chart Wizard** button on the **Tool Bar** and click the mouse (see Figure 14).

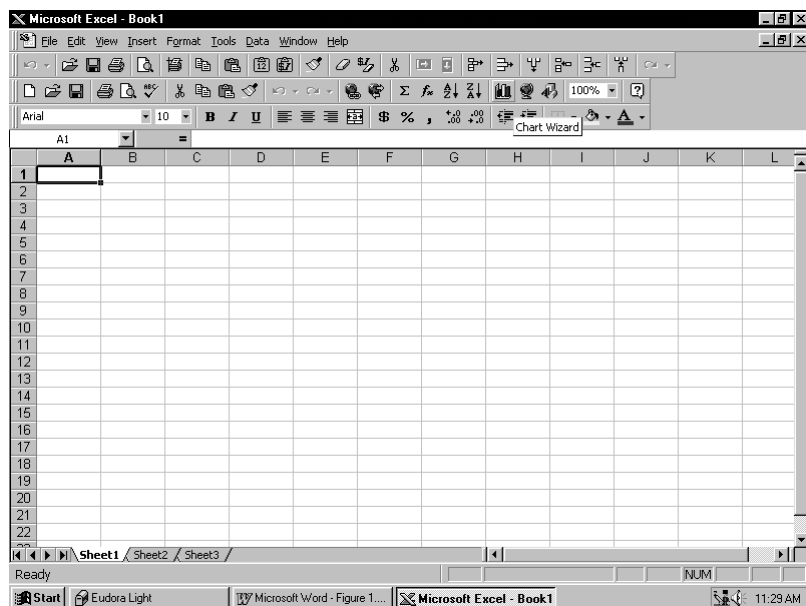


Figure 14

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Second: A pop up window entitled **Chart Wizard - Step 1 of 4 Chart Type** will appear (Figure 15A); you are to select the type of chart you want. Select the **XY (Scatter)** Chart by clicking on it. Five formats of a scatter chart will appear (Figure 15B). Select the smooth curve fit format (the second format shown). Then click the **Next** button.

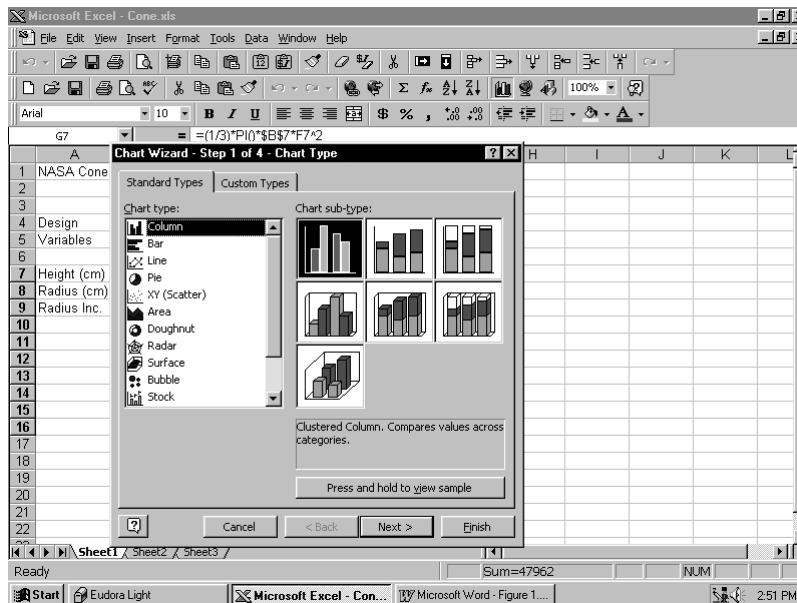


Figure 15A

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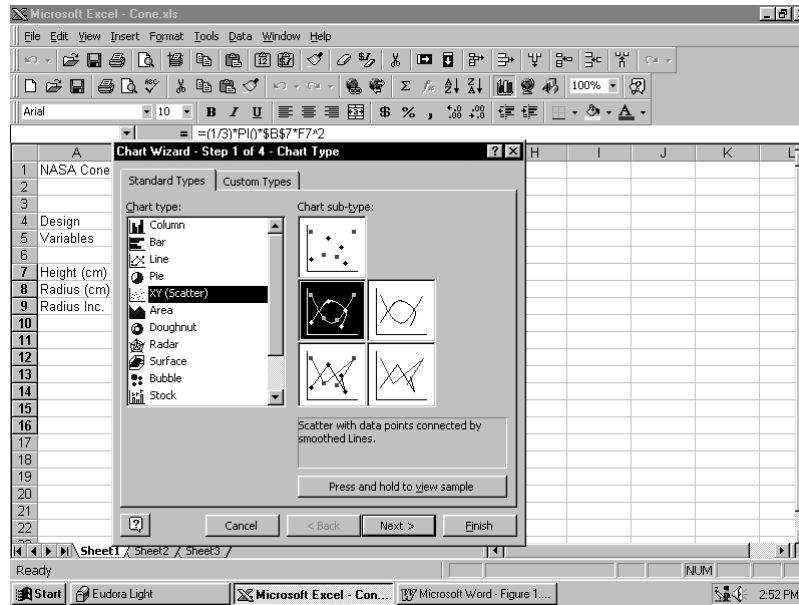


Figure 15B

Third: The dialog box titled **Chart Wizard - Step 2 of 4 Chart Source Data** will appear (Figure 16A); you are to select where the data for your chart is located. You may need to move this dialog box since it is probably in front of your data. To do this, move the pointer to the top of the dialog box. While pressing down the left mouse button, slide the mouse to the left or right (the dialog box will move with your motion), when you can see your data, lift up on the mouse button. Now to select the data you want plotted, move the pointer to cell **F3**, while pressing down on the left mouse button, select cell **F3** and slide the mouse to cover cell **G16**. A dotted line should appear around your 'calculation' area. Lift up on the mouse button. This range of data should appear in the dialog box as **=Sheet1!\$F\$3:\$G\$16** (see Figure 16B). You may need to move the dialog box back to the middle of your screen now. Two **radio buttons** in the dialog box designate how your data are organized in the selected region. In our case, the data are arranged in columns, make sure the **Columns** radio button is selected. Now click the **Next** button.

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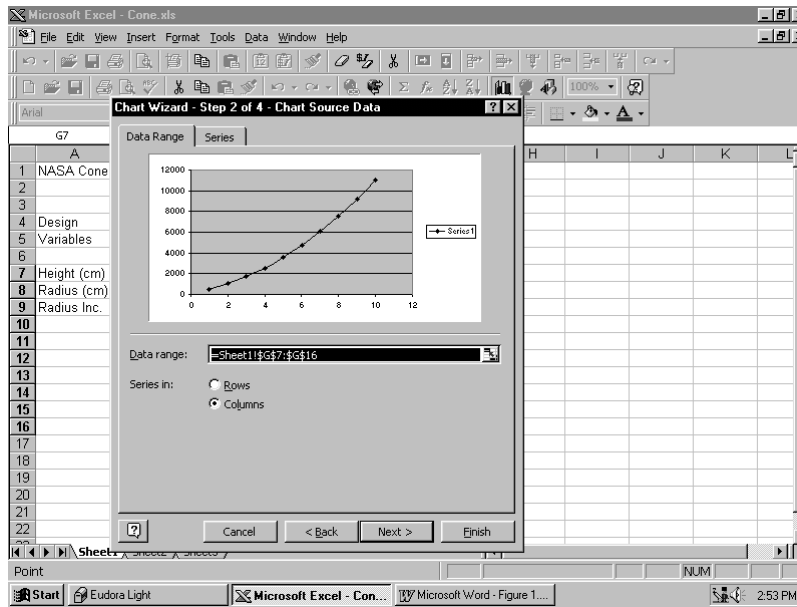


Figure 16A

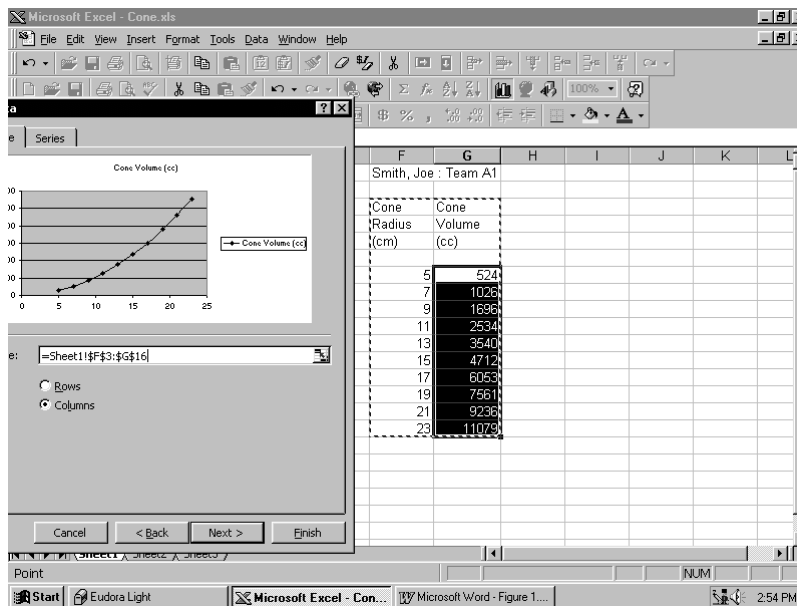


Figure 16B

Fourth: The dialog box titled **Chart Wizard - Step 3 of 4 Chart Options** will appear (Figure 17). There are five tabs at the top of the dialog box: **Titles, Axes, Gridlines, Legend, Data Labels**. Select **Titles**. For the **Title**, enter **NASA Cone Design Problem**. For **Category (X) Axis Label**, enter **Radius (cm)**. For **Value (Y) Axis Label**, enter **Volume (cc)**. Note: it is important when making charts to not only include the name of the

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axes, but also the appropriate units. Next select the **Legend** tab. Since we only have one curve plotted on our chart, we don't need a legend. Excel's default has the **Show Legend** radio button checked, uncheck this option by clicking on the radio button. Next select the **Gridlines** tab. We don't want the horizontal lines through our chart, so click on the checked radio button **Major Gridlines** under **Value (Y) Axis**. We don't want to make any other changes to the chart, but feel free to click on the other tabs to see what options are available. Now click the **Next** button.

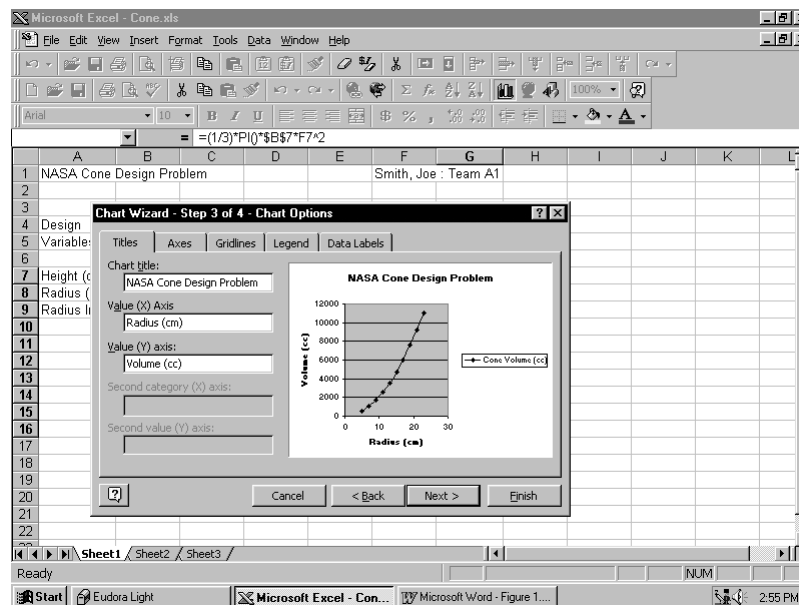


Figure 17

Fifth: The dialog box titled **Chart Wizard - Step 4 of 4 Chart Location** will appear (Figure 18). You can choose to have the chart displayed on a separate sheet within this Excel workbook file or you can have the chart displayed on the current sheet. For this assignment, put the chart on this sheet by clicking the **As object in** radio button. Note: sheets are shown as tabs on the bottom of the main Excel screen window. This is a way of keeping similar things in the same file, but separates things so that everything does not have to be on one sheet. Now click the **Finish** button.

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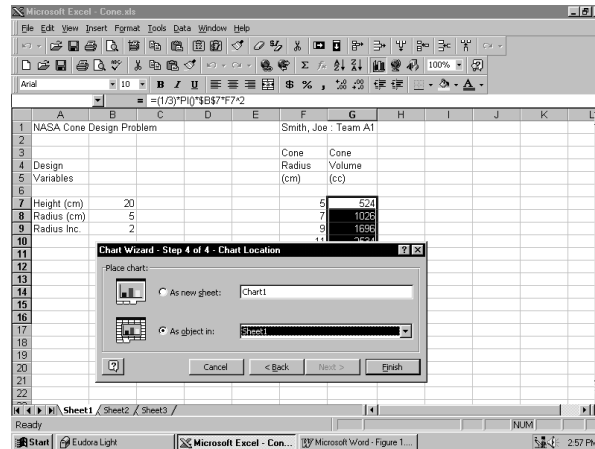


Figure 18

If you haven't done so recently, now would be a good time to save what you've done so far by clicking the **Save** button (looks like a diskette) on the **Tool Bar**.

Manipulating a Chart

The chart you generated is an embedded chart in your spreadsheet. You may wish to move it since it is probably covering some of your data. The chart has to be selected before it can be moved. Move the pointer anywhere within the chart area and click the mouse once. The chart's border will be altered and some sizing squares will appear around the borders of the chart (see Figure 19). By pressing down on the mouse again and dragging the mouse to the desired location, the chart will move. When you release the mouse button, the chart will remain at the new location.

If you wish to change the size of the chart, place the pointer on one of the black sizing squares along the border. The pointer will change into a cross hair. By pressing down on the mouse and moving the cross hair, you will enlarge or decrease the size of your chart.

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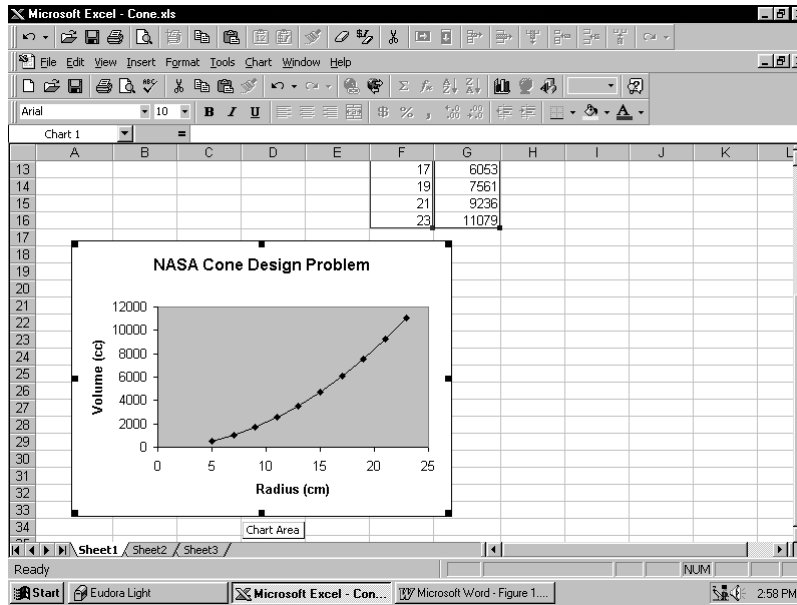


Figure 19

More Complex Chart

You can easily extend the above plot to include multiple curves. First you need to add another column of data. To do this, first label your data column. In cell **H3**, enter the word **Cone** and in cell **H4** enter the word **Area**. In cell **H5** enter (**sqcm**). In cell **H7** enter the formula: $=\pi() * F7 * (\$B\$7^2 + F7^2)^{0.5}$. When you have entered this formula, Excel will calculate and display a value of **323.828**.

Copy this formula into cell **H8** through **H16**. Adjust the significant digits of this column so that the values are integers. Now you have a table with one independent variable (radius) and two dependent variables (volume and surface area). We will now prepare a chart that has two curves. We will do this by modifying the chart we have already created.

First: Select the chart by moving the pointer to any place on the chart and clicking once. Note the sizing handles will appear around the borders of the chart. Select **Chart** on the **Menu Bar** and pull down to **Source Data** (see Figure 20A). A dialog box like Figure 20B will appear. As you did before move the dialog box if necessary and highlight the region to be

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plotted (F3 to H16). A new chart with 2 curves appears in the dialog box (see Figure 20C). Click **OK**.

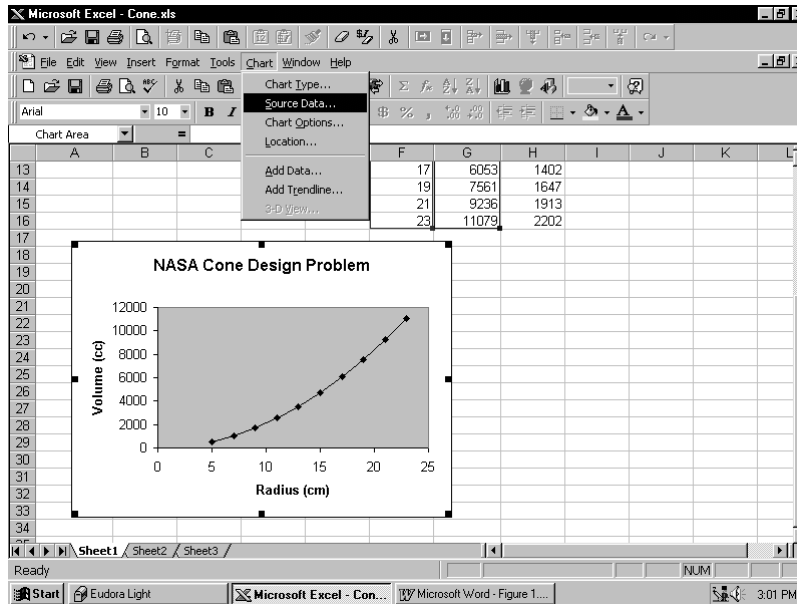


Figure 20A

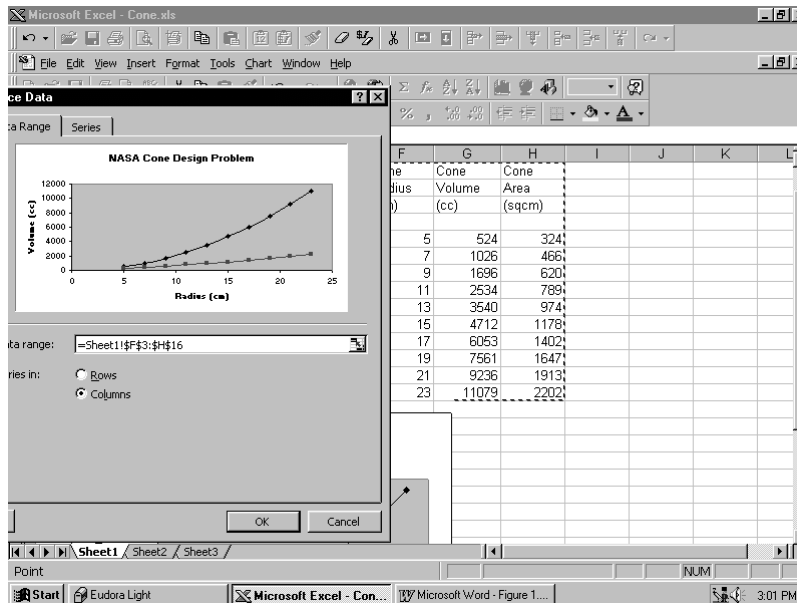


Figure 20 B

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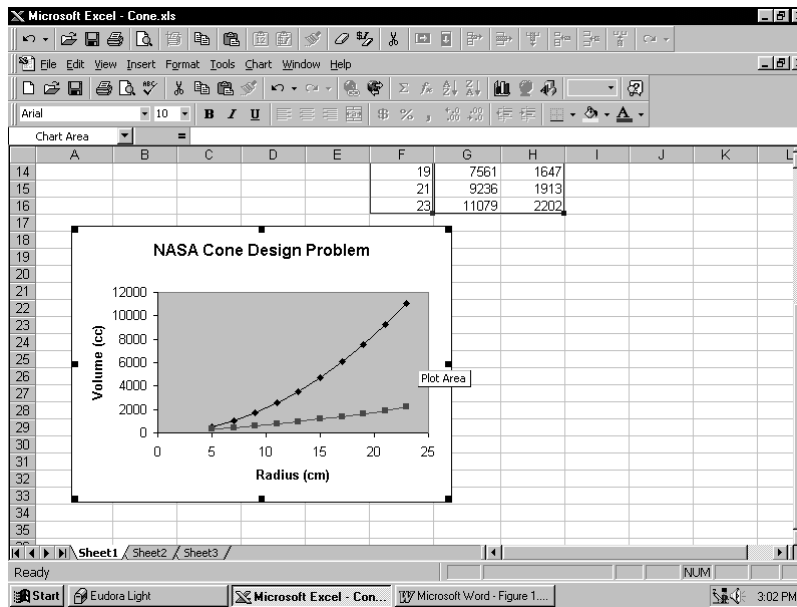


Figure 20C

Second: Since we now have 2 curves, we need a legend. Select **Chart** on the **Menu Bar** and pull down to **Chart Options** (see Figure 21A). When the dialog box appears, select the **Legend** tab and click the radio button **Show Legend**. The legend will appear with the appropriate labels (see Figure 21B). Click **OK**.

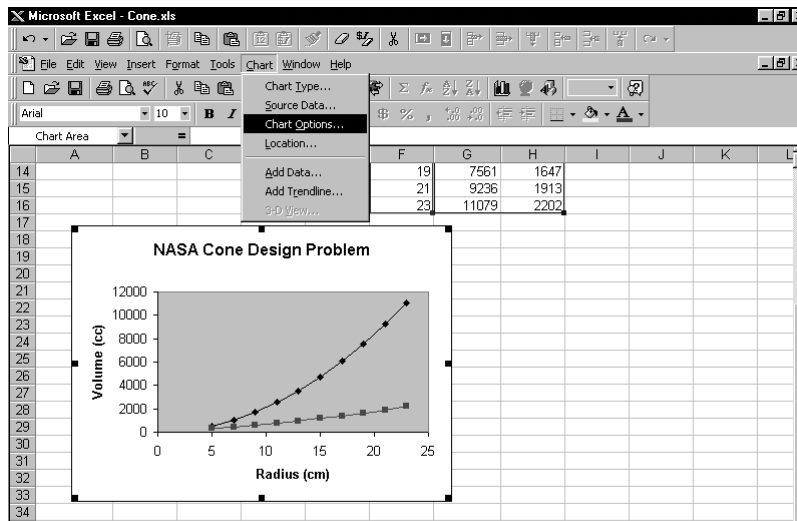


Figure 21A

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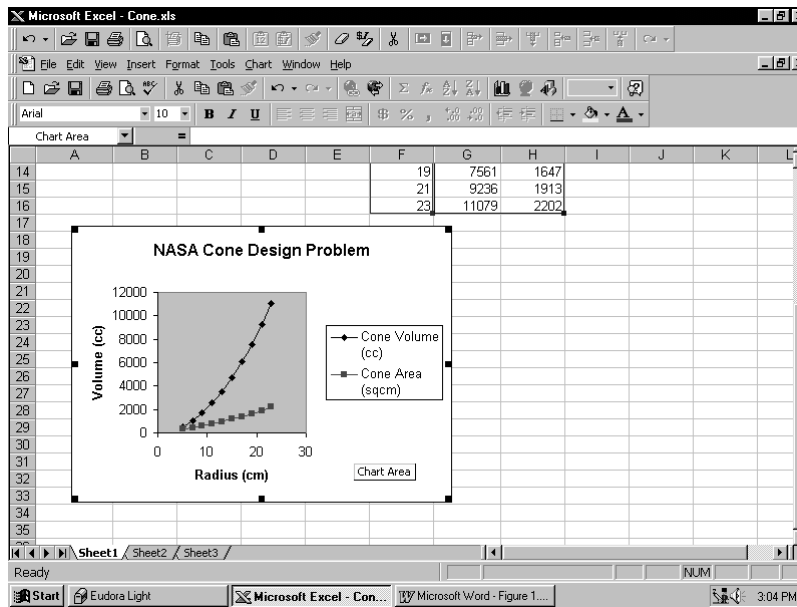


Figure 21B

Third: Since the second curve is not volume, we need a second Y axis with the appropriate labels. Select **Chart** on the **Menu Bar** and pull down to **Chart Type**. When the dialog box appears, select the **Custom Types** tab and move the pointer to the downward arrow. Click on this arrow until you see the format type **Lines on 2 Axes**. Move the pointer to this text and select it by clicking the mouse button (see Figure 22).

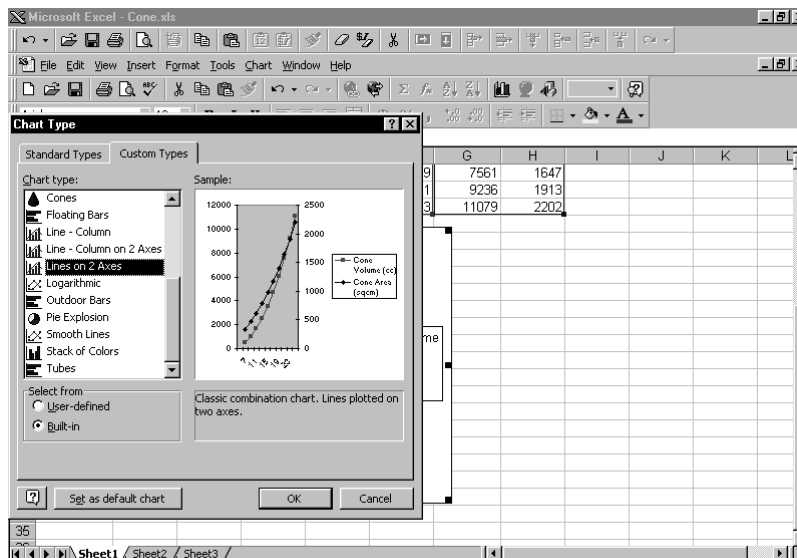


Figure 22

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Fourth: Finally we want to edit the Title and Labels on the chart. Select **Chart** on the **Menu Bar** and pull down to **Chart Options**. When the dialog box appears, select the **Labels** tab. For the **Title**, enter **NASA Cone Volume (cc) and Area (sqcm) vs. Radius (cm)**. For **Category (X) Axis Label**, enter **Radius (cm)**. For **Value (Y) Axis Label**, enter **Volume (cc)**. For **Secondary Value (Y) Axis Label**, enter **Area (sqcm)**. Click **OK** when done.

Your final chart should look like Figure 23.

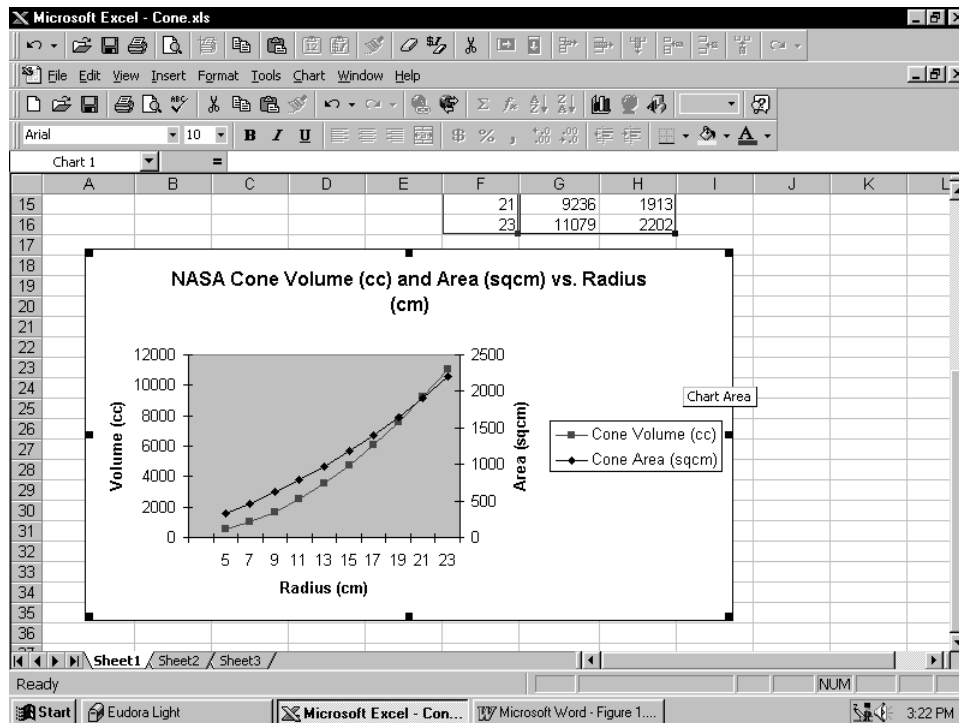


Figure 23

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Functions

Excel has numerous built-in functions to assist you with the calculations. Most of these functions will be used in your equations; therefore, they will be needed in the current cell as you enter a formula. You can select the **Function Wizard** on the **Tool Bar**; it is the button with the symbol **fx**. A dialog box will appear with two menu areas (see Figure 24A). The left hand column lists the **Function Category**, which allows you to locate the function you need more easily. For example, you may choose **the Math & Trig** selection if you are looking for the **cosine** function (see Figure 24B). The right hand column lists the names of the specific functions. You make your selection by clicking the mouse pointer on the desired function.

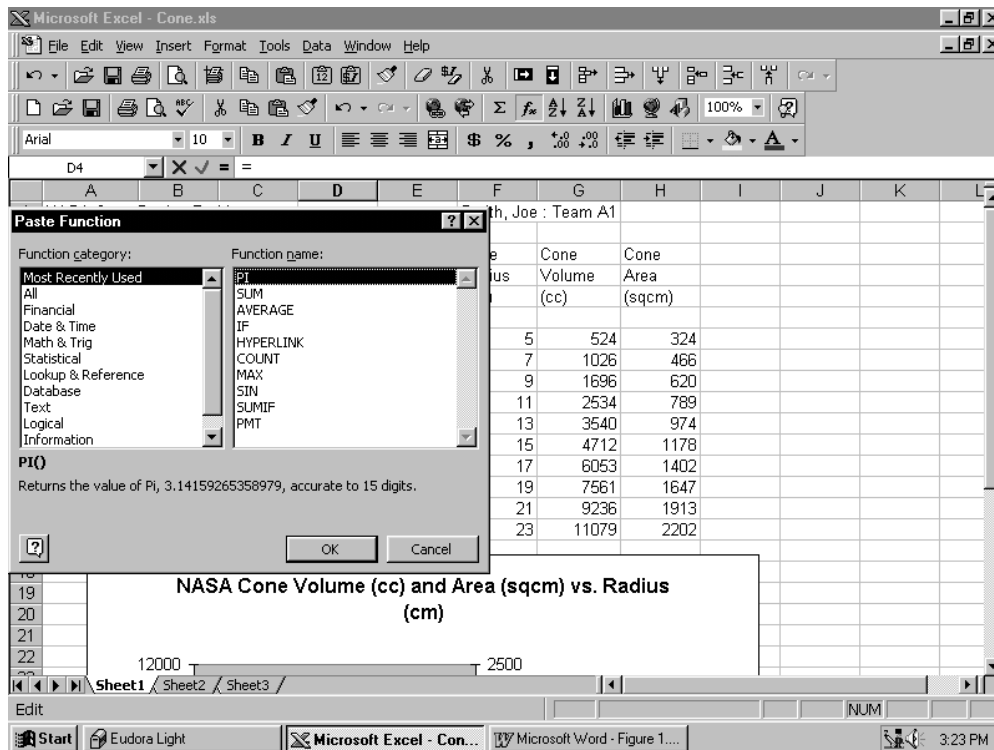


Figure 24A

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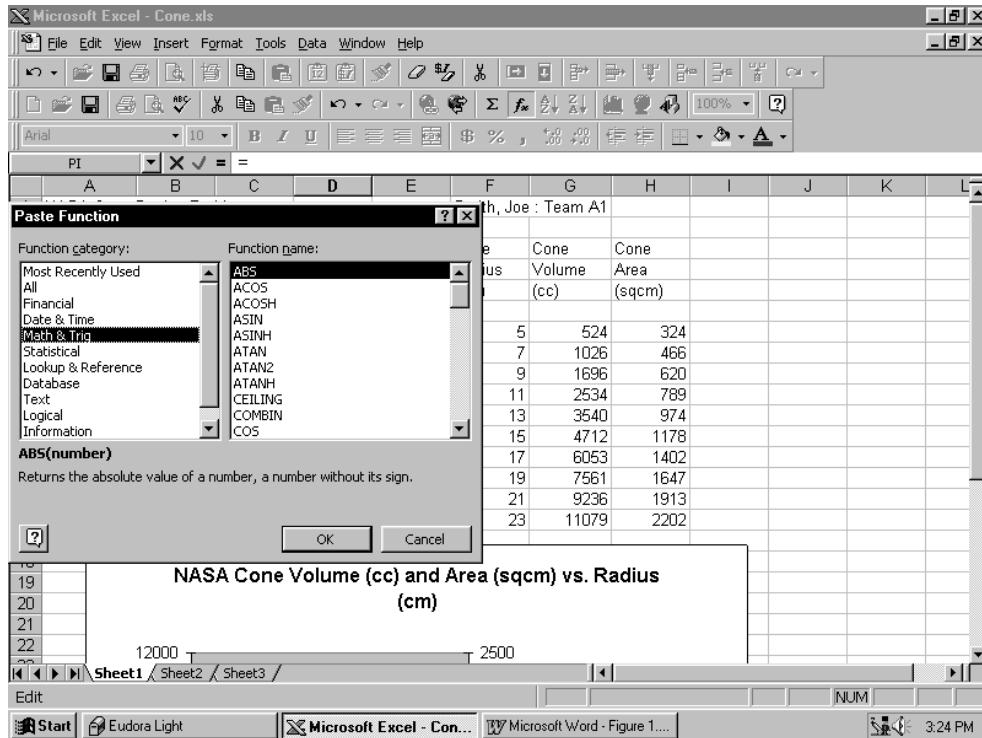


Figure 24B

Trouble Shooting, Viewing & Printing Formulas

Testing, validating or calibrating a spreadsheet model is an essential task in developing correct, robust, reliable, and useful models. Locating and correcting errors in spreadsheets can be facilitated by viewing and/or printing the formulas in your spreadsheet. This process destroys much of the formatting you've created, so save your work before viewing the formulas. It is often convenient to save the viewed formula version under a different filename.

From the **Menu Bar**, select **Tools**. Then select **Options** from the pull down menu. On the pop up window, select **View** (see Figure 25A). Mark the radio button **Formulas** under **Windows Options**. Select **OK**. The formulas are now displayed in the cells rather than the values (see Figure 25B).

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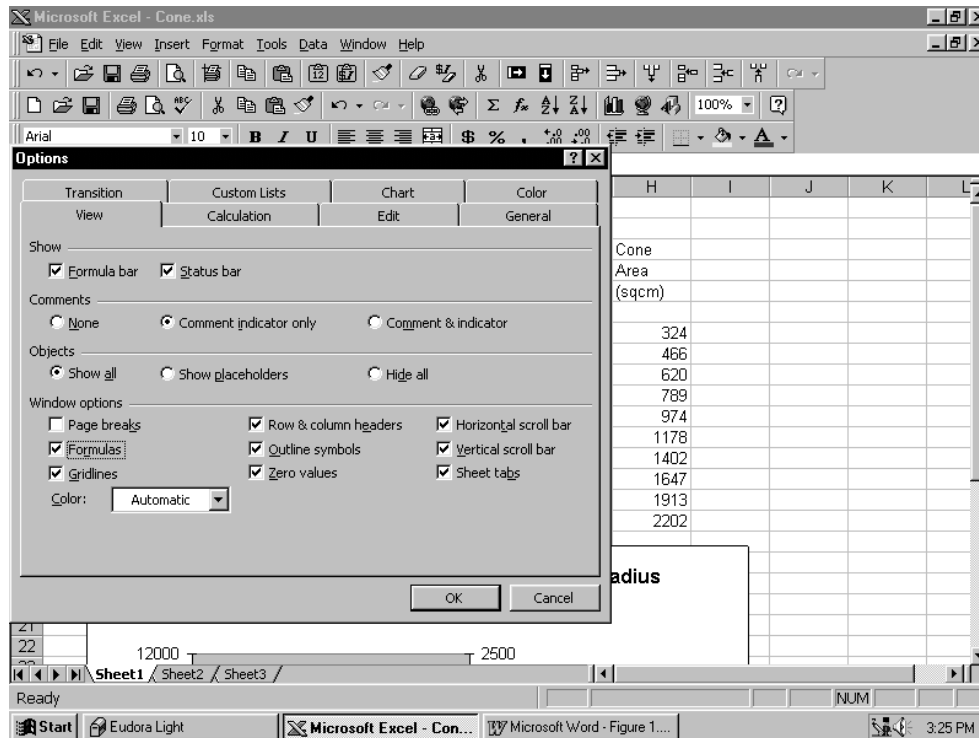


Figure 25A

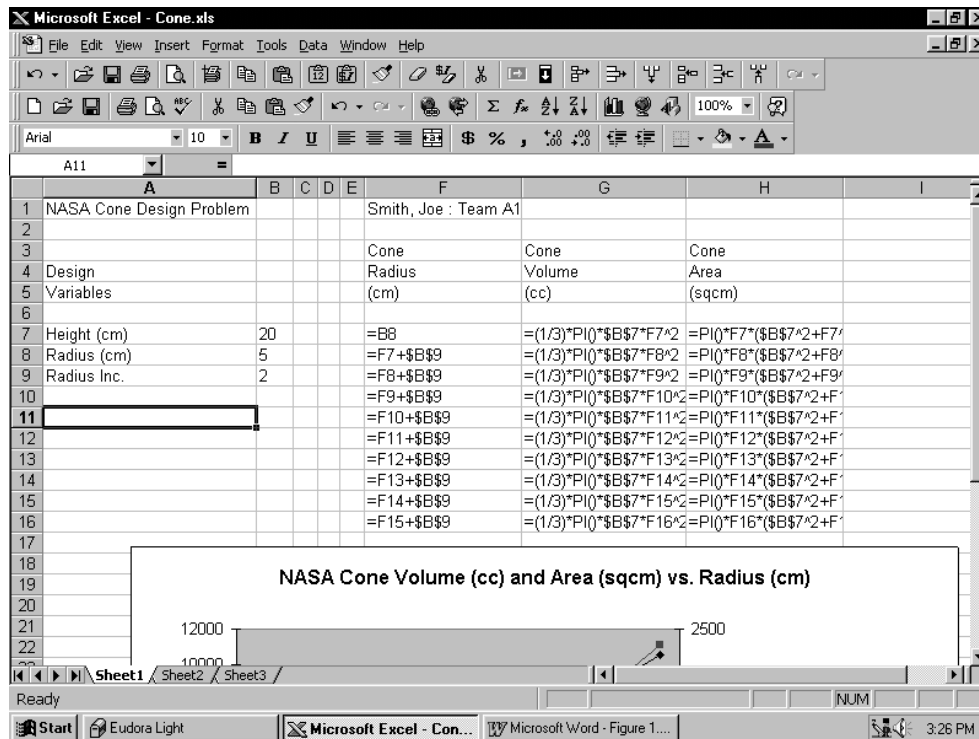


Figure 25B

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The entire formula is not displayed in the cells. To format the cells, select a cell with a long formula. Select **Format** on the **Menu Bar**, then **Column**, then **Auto Fit Selection**. The entire formula can now be seen.

Printing

To print, select **File** on the **Menu Bar** and then **Page Setup**. You can change your page to be printed vertical or landscape depending on how your spreadsheet is set up. You may wish to click the **Print Preview** button to see what your print out would look like. If it doesn't fit well on the page, you can click the radio button under **Scaling** to automatically adjust the scale so that it fits 1 page wide by however many pages tall so that the material is still readable. Once you have sized your document properly, click **OK**.

Now you can select **Print** from under **File** on the **Menu Bar**. The default (and the setting you will most often use) is to print the **active sheet**. If you have more than one sheet in your workbook, you may wish to print the **entire workbook**. If you have only one part of your spreadsheet that you wish to print (just the formulas), you can highlight that region (before going to **Print** on the pull down menu) and then clicking on **Selection** when you go to **Print**.

SECTION M

Competency Matrix for Workbook

The Competency Matrix for this workbook is presented in this section. This matrix lists the specific topics that the workbook authors feel are most important; it can also be viewed as an index to the workbook. In ECE 100 students are assigned to complete this index by inserting page numbers in the matrix to indicate where information on a certain topic is located in **this workbook**.

Engineering Core Active Learning, Assessment & Team Training

Name: **Smith, Oveyon Guamon**

Last Update 2/4/03 6:11 PM

The letters in each box indicate in which section of the workbook the competency is discussed

Number

Learning Outcome	Competency Category	Competencies	136	Affective Objectives			Cognitive Objectives					
				Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1 L e a r n i n g C u r r e	1 Introduction	A New Learning Culture	1.1 - 1	D			D					
		Also Self Evident Truths	1.1 - 2	D			D					
		ASU ... The Student is ...	1.1 - 3	D			D					
		Cone of Learning / Another View	1.1 - 4	D			D					
		Cooperative Learning Bromides	1.1 - 5	D			D					
		Definition	1.1 - 6	D			D					
		Harvard Assessment Seminars	1.1 - 7	D			D					
		Learning Pyramid	1.1 - 8	D			D					
		Learning Style / Consequences	1.1 - 9	D			D					
		Quality Principles	1.1-10	D			D					
	2 Active Learning Essential Elements	Face to Face Communication	1.2 - 1	D	D		D	D				
		Group (Team) Processing	1.2 - 2	D	D		D	D				
		Individual Accountability	1.2 - 3	D	D		D	D				
		Positive Interdependence	1.2 - 4	D	D		D	D				
		Social Skills Development	1.2 - 5	D	D		D	D				
	3 Active Learning Techniques	Think-Pair Share	1.3 - 1	D								
		Formulate-Share-Listen-Create	1.3 - 2	D								
		Numbered Heads Together	1.3 - 3	D								
		Jigsaw	1.3 - 4	D,G	D,G		D,G	D,G				
		Group Discussion with Talking Chips	1.3 - 5	D								
		Three Minute Essay	1.3 - 6	D								
		One Minute Paper	1.3 - 7	D								
		Structured Controversy	1.3 - 8	D								
				-	-	-	-	-	-	-	-	-

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Number

Affective Objectives			Cognitive Objectives					
Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
B, E, J			B, E, J					
B, E, J			B, E, J					
E			E					
E			E					
B, E, J			B, E, J					
E			E					
E			E					
E			E					
E			E					
E			E					
E			E					
E, K			E, K					
E, K			E, K					
E			E					

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Number

Affective Objectives

Cognitive Objectives

Learning Outcome	Competency Category	Competencies	Number	Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
3 T e a m s	1 Effective Meetings	Agenda	3.1 - 1	G			G					
		Evaluation	3.1 - 2	G			G					
		Facilitator	3.1 - 3	G			G					
		McNeill's Agenda Planner	3.1 - 4	G			G					
		One Hundred Mile Rule	3.1 - 5	G			G					
		Planning	3.1 - 6	G			G					
		Preparation	3.1 - 7	G			G					
		Records	3.1 - 8	G			G					
	2 Recurring Phases	Maintenance	3.2 - 1	G			G					
		Task	3.2 - 2	G			G					
	3 Roles, Responsibilities & Characteristics	Composition / Organization	3.3 - 1	G			G					
		Devil's Advocate	3.3 - 2	G			G					
		Encourager	3.3 - 3	G			G					
		Facilitator	3.3 - 4	G			G					
		Gate keeper	3.3 - 5	G			G					
		Leader	3.3 - 6	G			G					
		Member	3.3 - 7	G			G					
		Recorder	3.3 - 8	G			G					
		Sponsor	3.3 - 9	G			G					
		Time keeper	3.3-10	G			G					
	4 Stages of Team Development	Adjourning	3.4 - 1	G			G					
		Forming	3.4 - 2	G			G					
		Norming	3.4 - 3	G			G					
		Performing	3.4 - 4	G			G					
		Storming	3.4 - 5	G			G					

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Number

Learning Outcome	Competency Category	Competencies	136	Affective Objectives			Cognitive Objectives					
				Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
3 T e a m s	5 Decision Types	Consensus	3.5 - 1	G			G					
		Handclasp	3.5 - 2	G			G					
		Majority	3.5 - 3	G			G					
		Minority	3.5 - 4	G			G					
		Unanimity	3.5 - 5	G			G					
		Unilateral / Authoritarian	3.5 - 6	G			G					
	6 Sources of Power	Coercive	3.6 - 1	G			G					
		Expert	3.6 - 2	G			G					
		Legitimate	3.6 - 3	G			G					
		Reward	3.6 - 4	G			G					
		Unilateral / Authoritarian	3.6 - 5	G			G					
	7 Team Building Issues	Cohesiveness	3.7 - 1	G			G					
		Communication	3.7 - 2	G			G					
		Goal Specification	3.7 - 3	G			G					
		Interdependence	3.7 - 4	G			G					
		Roles and Norms	3.7 - 5	G			G					
	8 Task Classification	Additive	3.8 - 1	G			G					
		Compensatory	3.8 - 2	G			G					
		Conjunctive	3.8 - 3	G			G					
		Disjunctive	3.8 - 4	G			G					
		Optimize Quality	3.8 - 5	G			G					
		Optimize Quantity	3.8 - 6	G			G					
	9 Other	Definition	3.9 - 1	G			G					
		Use and Types of Teams	3.9 - 2	G			G					
		10 Common Team Problems	3.9 - 3	G			G					

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Learning Outcome	Competency Category	Competencies	136	Affective Objectives			Cognitive Objectives					
				Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
3 T e a m s	10 Social Norms	Code of Cooperation	3.10 - 1	C, H	C, H		C, H	C, H				
		Constructive Feedback	3.10 - 2	H	H		H	H				
		Definition of Social Norms	3.10 - 3	H			H					
		Enforcing Norms	3.10 - 4									
		Establishing Norms	3.10 - 5	H	H		H	H				
		Face to Face Communication	3.10 - 6	C, H			H					
		First Seek the Intersection	3.10 - 7	C, H			H					
		Intervention Techniques	3.10 - 8									
		Listening Skills	3.10 - 9	H			H					
		Listening Techniques	3.10 -10	H			H					
		Overcoming Group NOthink	3.10 -11	H			H					
		Paraphrase for Understanding	3.10 -12	H			H					
		Person to Person Communication	3.10 -13	H	H		H	H				
		Person to Team Communication	3.10 -14	H	H		H	H				
		Personal Communication Styles	3.10 -15	H	H		H	H				
		Roadblocks In Communication	3.10 -16	H	H		H	H				
		Talking Chips	3.10 -17	H	H		H	H				
		Team to Person Communication	3.10 -18	H	H		H	H				
		Team to Team Communication	3.10 -19	H	H		H	H				
	11 Total Quality Mgmt. Discussion Tools	Brainstorming Process	3.11 - 1	H	H		H	H				
		Affinity Process / Diagram	3.11 - 2	H	H		H	H				
		Force Field Analysis	3.11 - 3	H	H		H	H				
		Modified Nominal Group Technique	3.11 - 4	H	H		H	H				
		Process Checks (+/delta)	3.11 - 5	D, G			D, G					
		Process Checks (Likert)	3.11 - 6	D, G			D, G					

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Name: **Smith, Oveyon Guamon**

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Number

Learning Outcome	Competency Category	Competencies	136	Affective Objectives			Cognitive Objectives					
				Receiving	Responding	Valuing	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
6 A u t o n o m o u s L e a r n e r	1 General	Academic Journal	6.1 - 1	D			D					
		Competency Matrix	6.1 - 2	I, J	I, J		I, J	I, J				
		Design Notebook / Portfolio	6.1 - 3	J			J					
		Reflection Log	6.1 - 4	J			J					
		Work Log	6.1 - 5	J			J					
	2 Cognitive Domain	Application	6.2 - 1	I, J	I, J		I, J	I, J				
		Analysis	6.2 - 2	I, J	I, J		I, J	I, J				
		Comprehension	6.2 - 3	I, J	I, J		I, J	I, J				
		Evaluation	6.2 - 4	I, J								
		Knowledge	6.2 - 5	I, J	I, J		I, J	I, J				
		Synthesis	6.2 - 6	I, J								
	3 Affective Domain	Receiving	6.3 - 1	I, J	I, J		I, J	I, J				
		Responding	6.3 - 2	I, J	I, J		I, J	I, J				
		Valuing	6.3 - 3	I, J	I, J		I, J	I, J				
	4 Assessment Process	Checklists	6.4 - 1	B, J			B, J					
		Exceeds Expectations	6.4 - 2	B, J			B, J					
		Meets Expectations	6.4 - 3	B, J			B, J					
		Needs Improvement	6.4 - 4	B, J			B, J					
		No Credible Effort	6.4 - 5	B, J			B, J					
	5 Presentation Of Technical Work	Context	6.5 - 1	J			J					
		Discussion	6.5 - 2	J			J					
		Presentation Sandwich	6.5 - 3	J			J					
		Work (I.e., filling)	6.5 - 4	J			J					

TEAM SCHEDULE

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
7:00							
7:30							
8:00							
8:30							
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