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ABSTRACT

This document consists of a workshop presentation on active learning in the engineering classroom. Eight sessions focus on: (1) the format and purpose of the workshop, which is designed to help instructors use active learning principles in the classroom; (2) the state of instruction in the engineering sciences; (3) the stages of knowledge and learning and the use of competency matrices in student evaluation; (4) the essential elements of active learning, including positive interdependence, individual accountability, group processing, and face-to-face interaction; (5) a proposed learning culture and the effectiveness of various learning and teaching styles; (6) the roles of team leaders, facilitators, and members in team-based active learning; (7) the structure and design of active learning exercises and homework problems; and (8) student evaluation. An appendix contains notes on change in the learning environment, the process of change, and levels of learning. (MDM)

Active Learning in the Engineering Classroom

Prepared by

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Active Learning in the Engineering Classroom

Session 1. (10 minutes / 10 minutes total)

Getting Started

Forming Groups
Focus on Facilitator Signal
Issue Bin
Reflection (the Academic Journal)
Code of Cooperation

Session 2. (20 minutes / 30 minutes total)

Why are we (me and my absent team member) here?
How did we get here?
What is our basic operating premise?

Question: How should Engineering Faculty become aware
of the need for change?
Active Learning Delivery: Formulate-Share-Listen-Create (Think-Pair-Share)

Session 3. (15 minutes / 45 minutes total)

What Should We Expect from Education?

Levels of Knowledge and Learning

Stages of Knowledge (Mr. House of Hewlett Packard)
Stages of Learning (Bloom's Cognitive Domain Taxonomy)

Evaluation Matrix (Competency Matrix)

Session 4. **(20 minutes / 65 minutes total)**

Essential Elements of Active Learning (PIGS Face)

Active Learning Delivery: Jigsaw

Session 5. **(20 minutes / 85 minutes total)**

A Proposed Learnin` `ulture : Video Tape (6 minutes)

N.B. Workshop Notes Include Materials from the Video Tape

Session 6. **(15 minutes / 100 minutes total)**

Active Learning (Bits and Pieces)

- Team Roles and Responsibilities
- Forming Groups
- Code of Cooperation (revisited)
- Cooperative Learning Structures and Procedures
- Cooperative Learning Bromides

BREAK **(20 to 30 minutes but lunch or next day is better)**

Session 7. **(60 minutes / 60 minutes total)**

Heirarchical Structures for Students

Active Learning Exercise : Conservation of Linear Momentum

Prompt (summary of today's material)
Structure (for the task)
Task (problem or whatever to illustrate today's material)
Individual Accountability Check Sheet

Session 8. (30 minutes / 90 minutes total)

Evaluation Revisited

Principles of Good Practice for Assessing Student Learning
Student Assessment Using a Competency Matrix
Grades and the Matrix

Process Check

Reflection

Disclaimer

The material presented in this workshop is based on fictional accounts of dramatized experiences of non existent faculty members and any resemblance to actual institutions of higher education or faculty members therein is coincidental.

Please do not confuse enthusiasm or interest with any form of actual expertise or advanced stage of knowledge. The views expressed herein are not those of the Foundation Coalition.

The Environment and the Purpose

- Learning Environment
  - Active (as opposed to Passive)
  - Group or team based
  - Workshop facilitators (not Lecturers)
- Purpose and Expected Participant Outcomes
  - An understanding of the structure and principles of Active Learning in the Engineering Classroom
  - An ability to apply the sturucture and priciples in the classroom based on a simulated classroom experience

Getting Started

- Forming Groups
- 'Focus on the Facilitator' Signal
- Issue Bin
- Reflection (e.g., the Academic Journal)
- Code of Cooperation

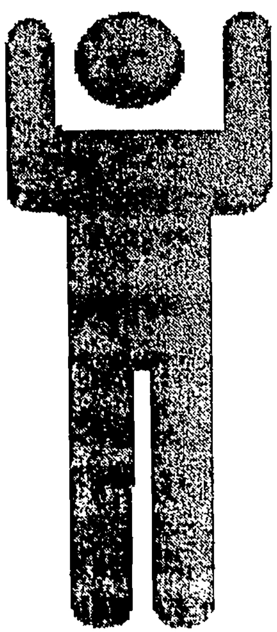
Forming Groups

- Groups of 5 or more will be appropriate for this workshop.

- Take a seat an any table or arrange the chairs in the room to accommodate 5 or more people.

- Make an effort to seat yourself with people you don't know or at least don't know very well (i.e., as the students do in class on the first day!)

'Focus on Facilitator' Signal



The facilitator needs you attention:

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

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 workshop
  - items that can or should be the subject of future workshops
- Paraphrase the issue and record on the board or a piece of paper which is always visible
- At the conclusion of the session or workshop, 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 workshop.

Reflection (the Academic 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..

What to Write. Use your 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 me, express confusion, and explore possible approaches to problems in the course.

When to Write. Try to write in your 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. The quantity you write is as important as the quality. Use language that expresses your personal voice -- language that comes natural to you.

Reflection
(the Academic Journal continued)

Suggestions:

1. Chose a notebook you are comfortable with' I recommend a small (6" x 9") looseleaf.
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. I'll ask to see your journal at least twice during the term; I'll read selected entries and, upon occasion, argue with you or comment on your comments. Mark any entry that you *don't want me to read* and I'll honor your privacy. None of the 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 -- Corespondent. Choose a colleague (a fellow student in your group, for example) to read and respond to your journal entries.

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

Code Of Cooperation

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. Maintain confidentiality; who says what stays in the team room; minutes, results, reports, etc. are shared with appropriate individuals.
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

Why are we here ?

- **Zilmon says**

To be successful in life requires that a person know only one thing;

You must know what you don't know !

How did we get here ?

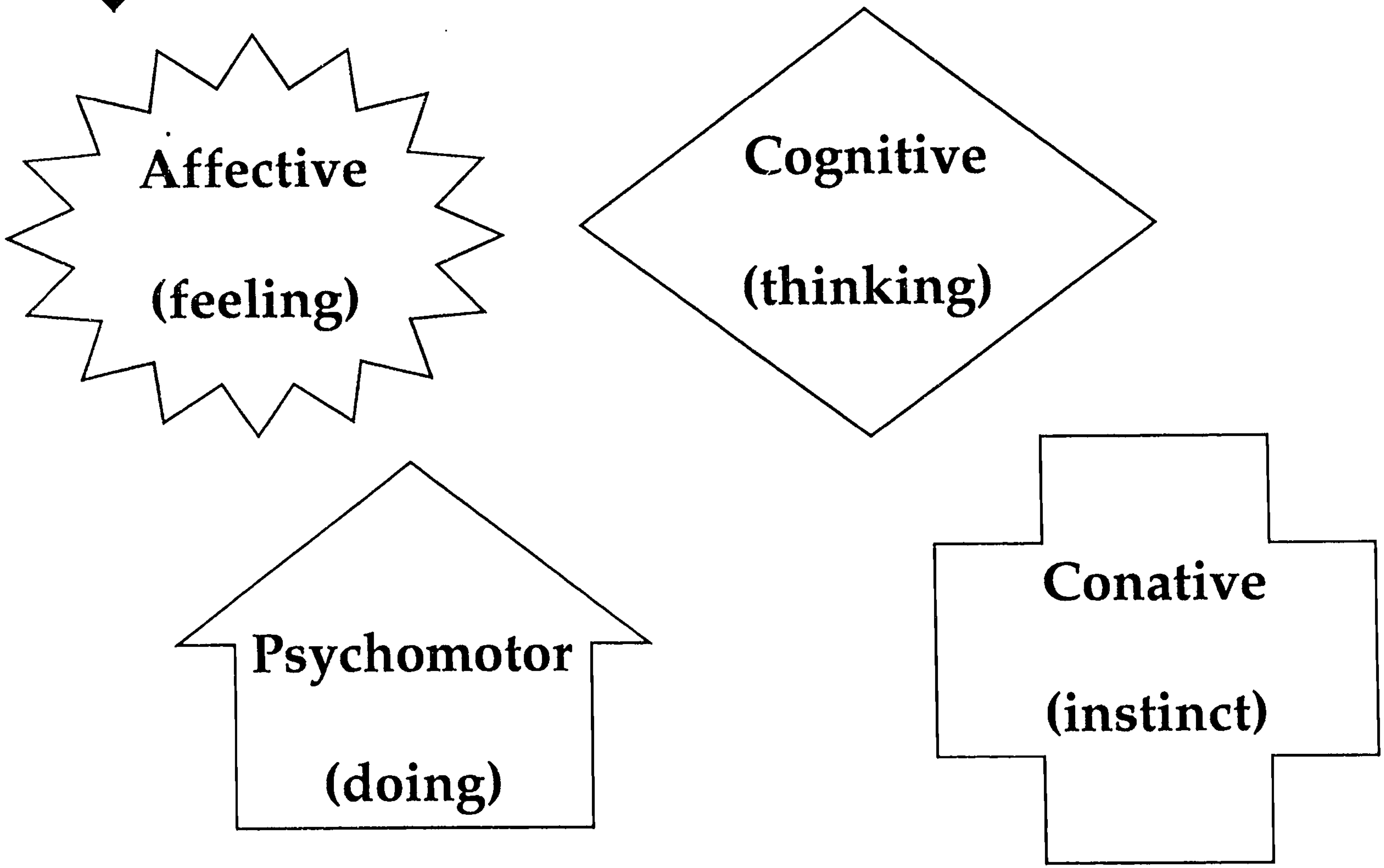
The Way We Wish it had Happened (1)	The Way it Should Have Happened (2)	The Way it Really Happened (3)

(1) We read the
The Board on Engineering Education Working Paper on Major Issues in Engineering Education, section III.B Undergraduate Engineering Experience, Issue #2 - Are Teaching methods appropriate?, Options for Action (Issue #2), Option "G" : Increase faculty awareness of cognitive research,
and decided to do something about finding out what we don't know.

(2) How should it have happened in a well run institution of higher education?

(3) In a state of despair and desperation about our failed attempts at improving student performance in our courses, we were chasing any and all rabbits, possums and raccoons when we fell quite by accident into the swamp of cognitive science where we still languish knowing we don't know anything!

Cognitive Science Domains



Formulate-Share-Listen-Create

Focus Question	How should change take place in a well run institution of higher education ?

1. Formulate your answer to the question (individually)

2. Turn to the person next to you (find a partner)

   Share your answer

   Listen carefully to your partner's answer

3. Create a new answer through discussion

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 is 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. (12)

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

"What Should We Expect From Education?" (8, 9)

- Knowledge -- enables us to understand what we learn in relationship to what we already know
- Know-How -- enables us to do, it puts knowledge to work
-
- Wisdom -- the ability to decide what is important and what is not
- Character (3) -- a combination of Knowledge, Know-How and Wisdom, coupled with motivation
  - honesty, initiative, curiosity, truthfulness, integrity, cooperativeness, ability to work alone, ability to work in a group, self esteem (from Covey, 7 Habits of Highly Effective People ...)

Stages of Knowledge*

- You do not know that you do not know (unconscious incompetent)
- You know that you do not know (conscious incompetent)
- You know that you know (conscious competent)
- You do not know that you know (unconscious competent)

*Mr. House - Hewlett Packard

Stages of Knowledge

Relating Awareness and Competence Levels

Competence (Level of Learning)

Self - Awareness (Degree of Internalization)	Low	High	
	2 You know that you do not know (Conscious Incompetence)	3 You know that you know (Conscious Competence)	High
	1 You do not know that you do not know (Unconscious Incompetence)	4 You do not know that you know (Unconscious Competence)	Low

'Conscious Competence - The Mark of a Competent Instructor', *Personnel Journal*, July, 1979, pp. 538-539

Another View of Stages of Learning (6)

- Knowledge

  I have basic information,
  but cannot explain it to others.

- Comprehension / Understanding

  I understand and can explain this
  information to others (requires knowledge).

- Application

  I can apply this concept or information to
  different situations
  (requires knowledge and comprehension).

Another View of Stages of Learning (Continued)

- **Analysis & Synthesis**

  I can play with the concept, break it apart and create new variations (requires knowledge and comprehension).

- **Evaluation**

  Having gone through the preceding states, I have a deep appreciation for this concept (requires knowledge, comprehension, application, and analysis & synthesis).

Competency Matrix

- A 'snap shot' of a person's level of learning
  for a variety of concepts or skills

- An L matrix of concepts to be learned
  versus
  stages (or levels) of learning

- The matrix is filled out by person being evaluated

- It must be constructed by the person responsible for
  (1) establishing the course objectives, and
  (2) designing both the learning experiences and
  assessment instruments required to achieve the
  course objectives.

Sample Evaluation Matrix

Instructions for filling in the matrix

a. For each competency area darken the row up to and including the column which indicates your current level of learning for the competency. You can refer to the following pages to assist you in understanding the meaning of these levels of learning.

b. If you do not know or recognize a competency area then you only blank the first column (Before Knowledge)

c. Each time you re-evaluate your state of learning for a competency, if your level of learning has increased then move the bar farther to the right using a different color or pattern to fill in the column(s).

Competency Category	Competencies	Before Knowledge	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Cooperative Learning	Code of Cooperation							
	Face to Face Interaction							
	Individual Accountability							
	Jigsaw							
	Structure Before Task							
	Structured Controversy							
Teams	Gatekeeper							
	Storming							
	Team Diversity							
	Team Member							
Assessment	Competency Matrix							
	Grades							
	Knowledge							
	Know-How							
	Stages of Learning							

Essential Elements of Active Learning (4)

- <u>P</u>ositive Interdependence
- <u>I</u>ndividual Accountability
- <u>G</u>roup Processing
- <u>S</u>ocial Skills
- <u>F</u>ace to Face Interaction

"<u>P</u> <u>I</u> <u>G</u> <u>S</u> <u>F</u>ace"

A Simple Jigsaw Exercise

- Count off in your groups from 1 to 5
- Depending on your number you will read a paragraph (2 minutes)
  - 1'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 30 second tutorial on your reading to teach your other group members what you have learned (2 minutes)
- In sequence deliver the tutorials (4 minutes)
- I will call, at random, for discussion of these paragraphs (2 minutes)

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 reward, being dependent on each other's resources, or a division of labor.

Individual Accountability

Individual accountability/Personal Responsibility requires the teacher 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).

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.

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.

Face to Face Interaction

Face to face promotive interaction exists among students when students

orally explain to each other how to solve problems,

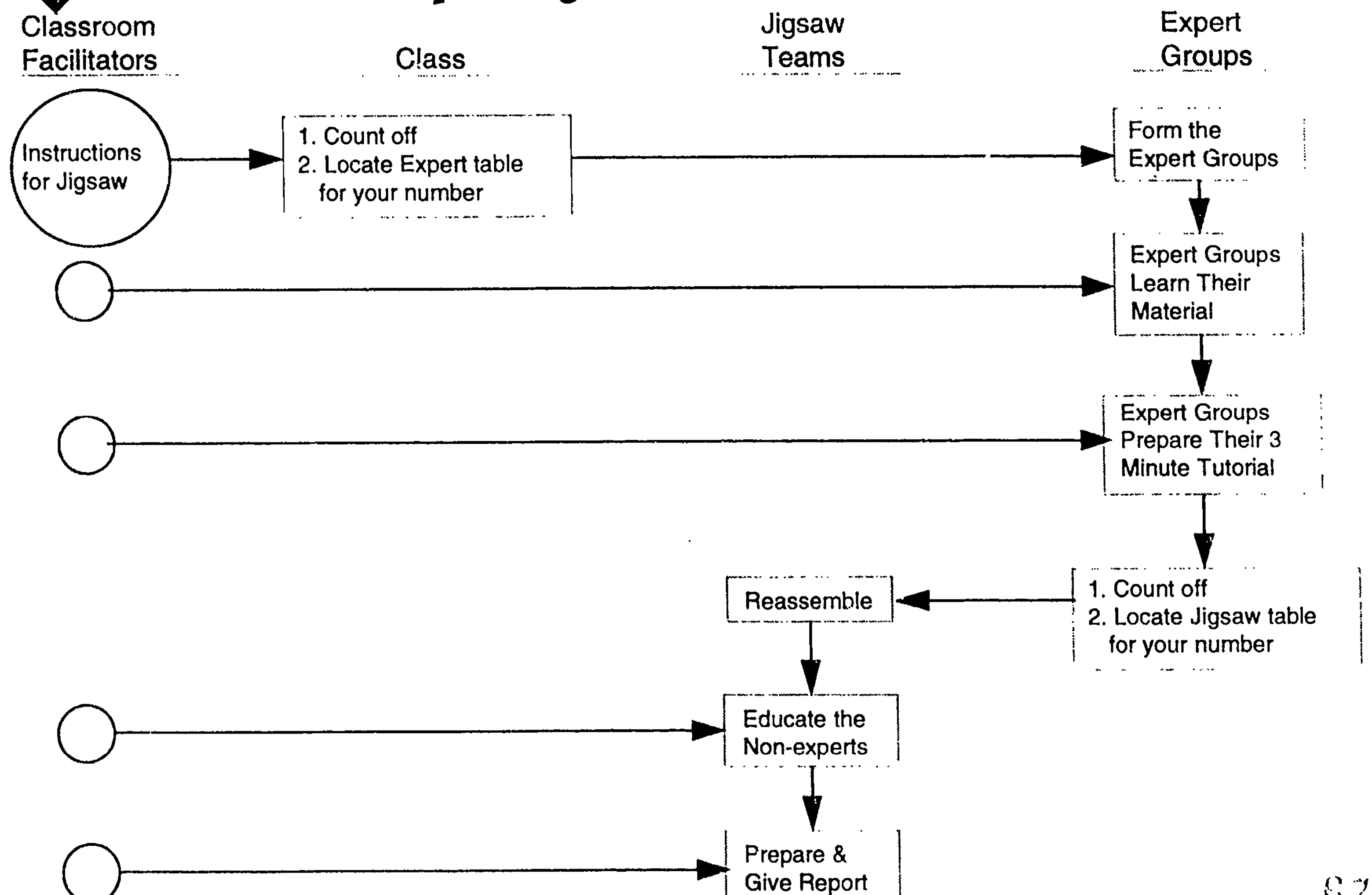
discuss with each other the nature of the concepts and strategies being learned,

teach their knowledge to classmates, and

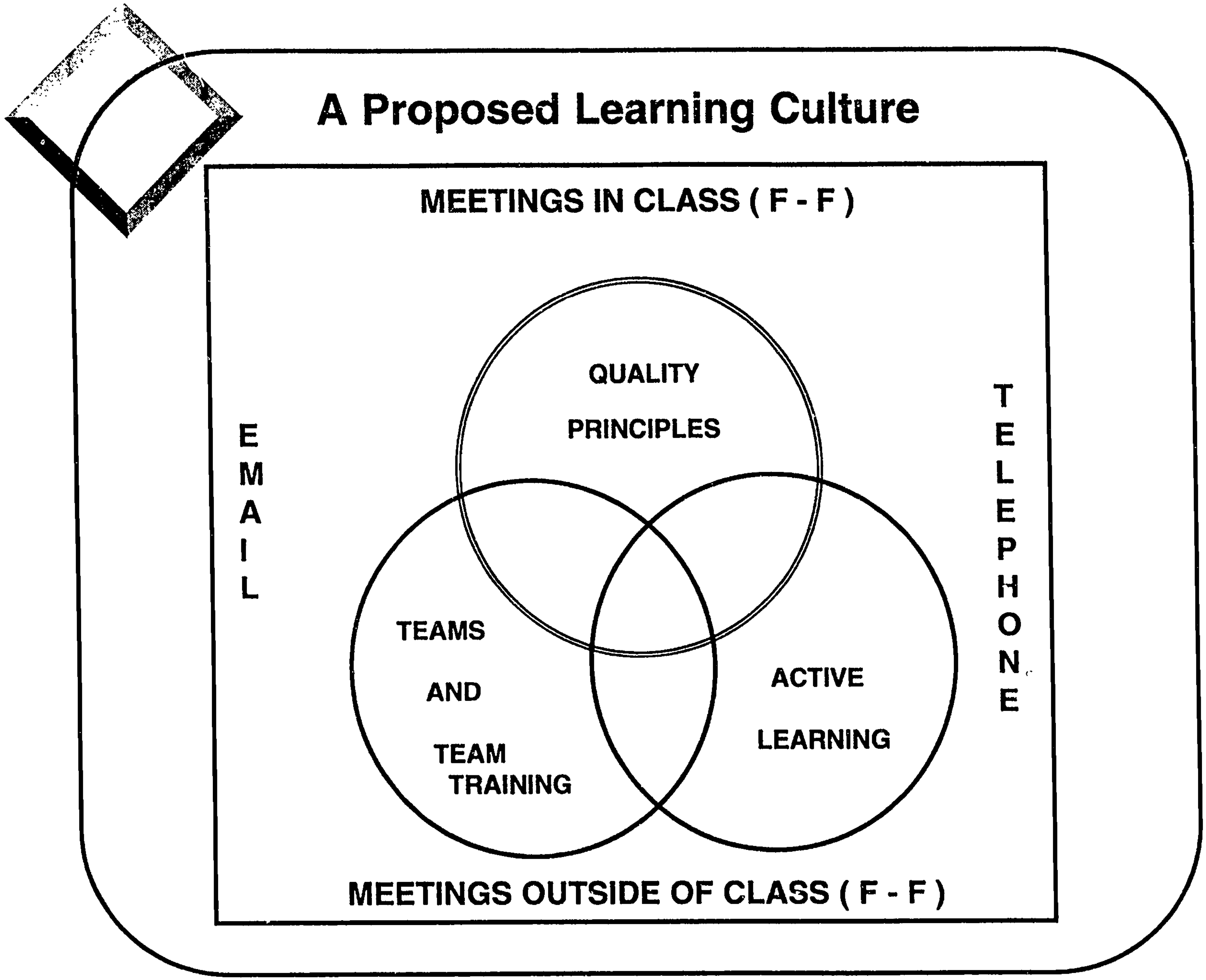
explain to each other the connections between present and past learning.

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

Complex Jigsaw Example Deployment Flow Chart



Slide 31


A Proposed Learning Culture
MEETINGS IN CLASS (F - F)
QUALITY
PRINCIPLES
EMAIL
TELEPHONE
TEAMS
AND
TEAM
TRAINING
ACTIVE
LEARNING
MEETINGS OUTSIDE OF CLASS (F - F)

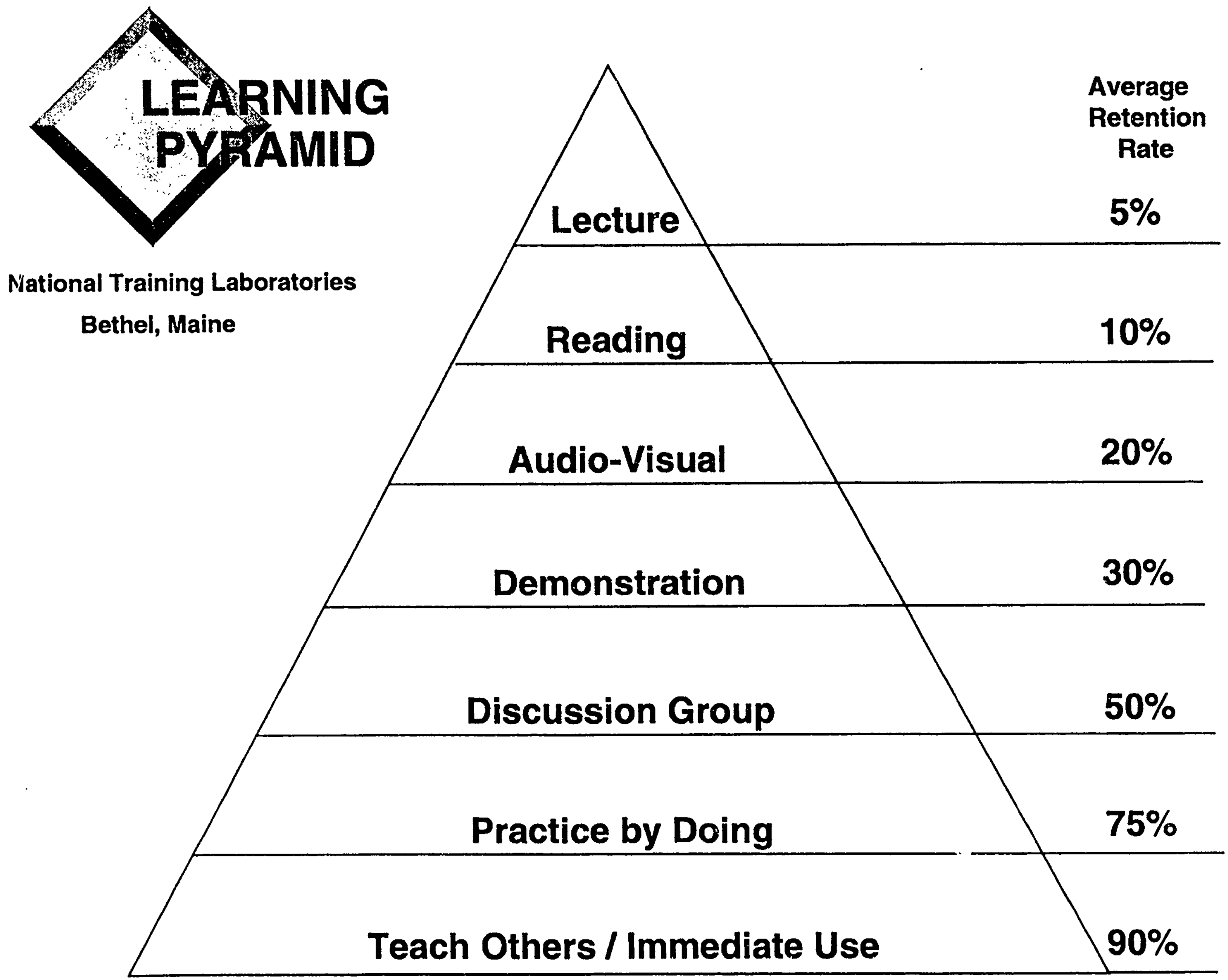
Active (Cooperative) Learning

- A technique used <u>in the classroom</u> which employs student-student and student-facilitator (faculty) interaction in various forms to convert the learning environment from PASSIVE to ACTIVE

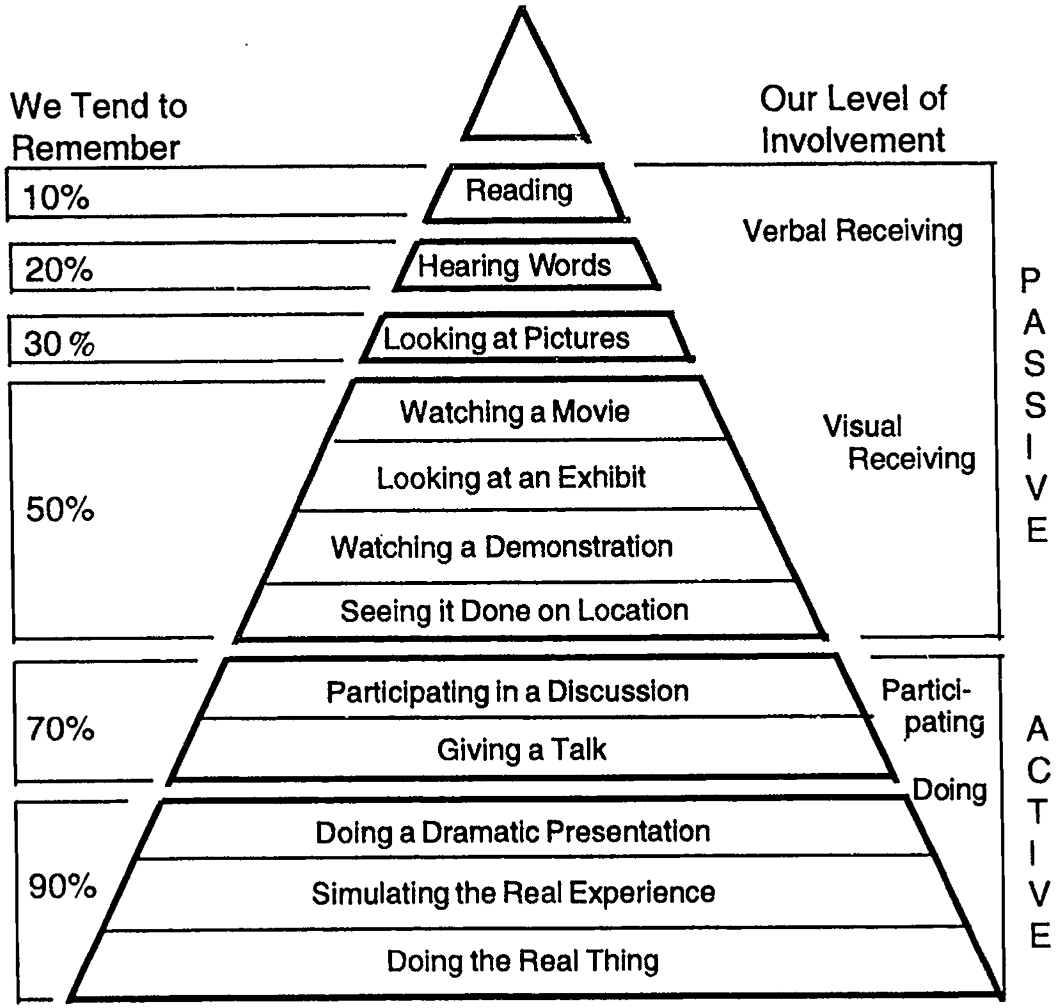
- Enhances learning

- Substantially improves retention

- Increases in value as the material increases in conceptual difficulty


LEARNING
PYRAMID
National Training Laboratories
Bethel, Maine
Average
Retention
Rate
Lecture
5%
Reading
10%
Audio-Visual
20%
Demonstration
30%
Discussion Group
50%
Practice by Doing
75%
Teach Others / Immediate Use
90%

Cone of Learning / Another View



Effectiveness of Learning Modes

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)

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. *Sequential* or *global* 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.

*Excerpts from a review of Richard J. Lights's 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

What Employers Want : A Summary

- 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

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

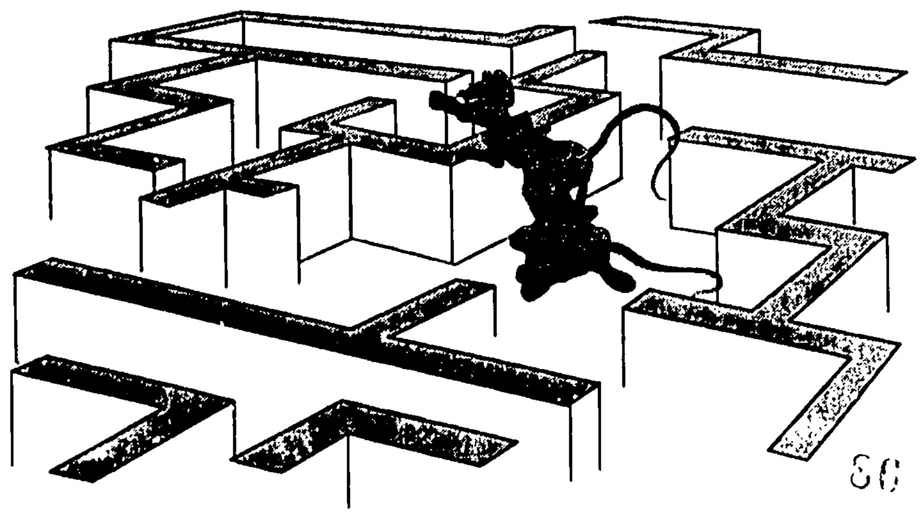
Benefits to Students

- "I understand the material better."
- "We learn by teaching each other."
- "...stay more focused for a longer time"
- "...higher level of concentration."
- "... increased ability to express self."
- "...improved team participation."
- "...taught me responsibility to the group."
- "...less notes, more learning time."
- "It has brought my mark up."

Source: BCIT student course evaluations (1991)

Teaming

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



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

Good Practice in Undergraduate Education (2)

1. Encourages Student-Faculty Contact
2. Encourages Cooperation Among Students
3. Encourages Active Learning
4. Gives Prompt Feedback
5. Emphasizes Time on Task
6. Communicates High Expectations
7. Respects Diverse Talents and Ways of Learning

Team Roles & Responsibilities (Bits & Pieces)

Team Leader

- Leads team through problem solving process
- Invests appropriate amount of time on the project
- Maintains accurate records of team activities and results
- Prepares for each team meeting
- Provides structure and guidance to allow maximum participation
- Influences team decisions equally with team members

Team Roles & Responsibilities (continued)

Team Member

- Invests appropriate time on the project
- Is committed and fully involved in project
- Participates equally in:
  - Defining problems
  - Investigating problems
  - Defining solutions
  - Documenting solutions
- Represents his/her organization's interest

Team Roles & Responsibilities (continued)

Team Facilitator

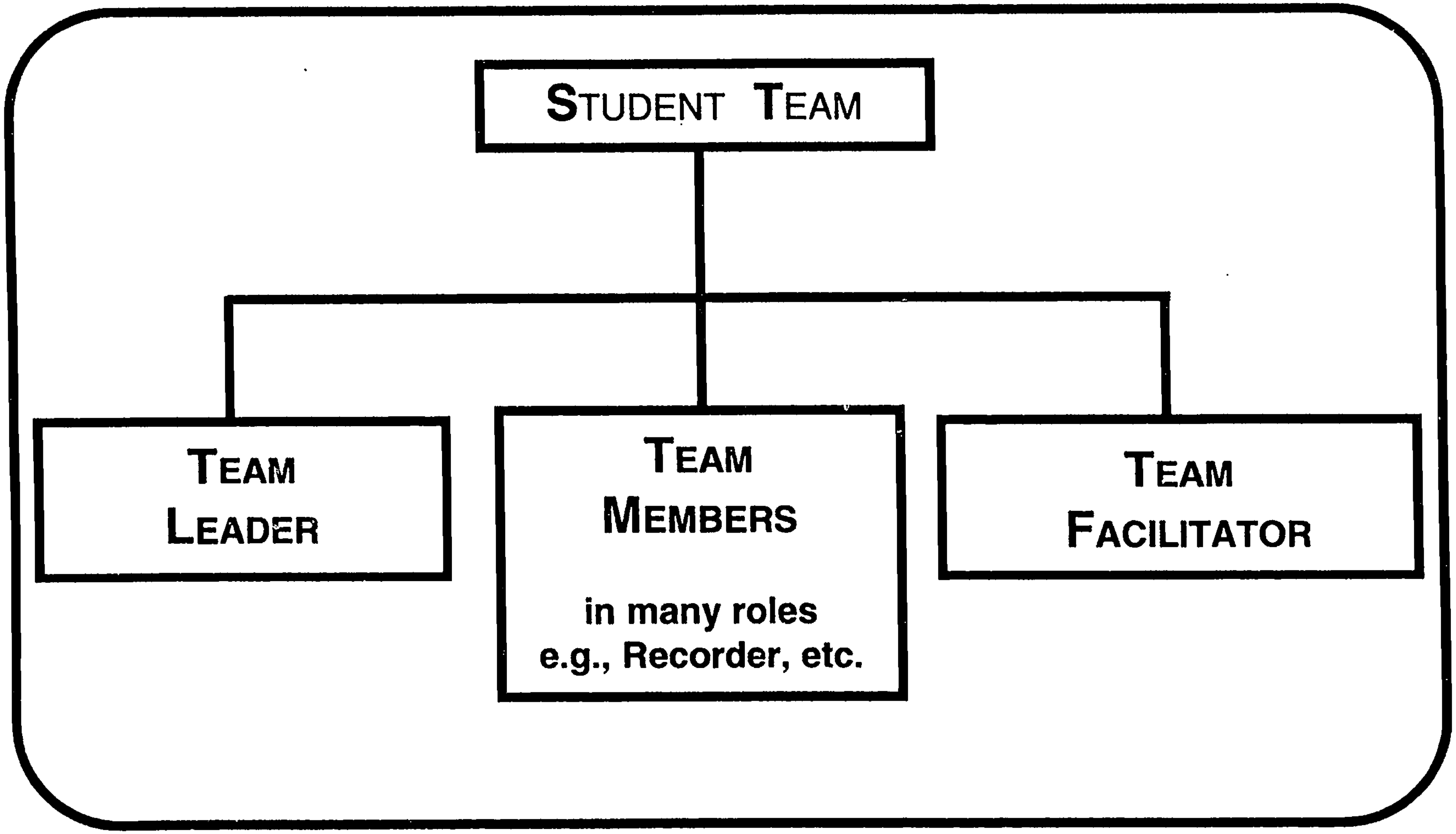
- Assists team leaders in training team members
- Suggests alternative methods and procedures
- Functions as a coach/consultant to the team
- Assures understanding of the team *process*
- Remains *neutral*
- Monitors the *process* rather than the task
- Attends team meetings and provides feedback on team's process and progress

Team Roles & Responsibilities (continued)

Additional Team Member Roles

- Team Recorder
  - Writes down all the ideas and material generated during the working meeting
- Team Encourager
  - Makes sure that everyone on the team is getting positive recognition for their contribution
- Team Gatekeeper
  - Makes sure that all members of the team are participating
- Team Devil's Advocate
  - Makes sure that opposing ideas are brought up and discussed
- Team Timer
  - Makes sure that team stays on its time budget for the various tasks
- Team Resource Holder
  - This person holds team resources (e.g., calculators, instructions, paper & pencils, etc.)

Student Team Composition (Bits & Pieces)



Forming Groups (Bits & Pieces)

- Groups of 4 and 5 are best
  for most cooperative learning activities

- Strive for diversity within each group

- Best if instructor forms groups
  but this is not critical if groups have diversity

- The instructor may choose to reformulate the groups
  during the semester (perhaps as many as five times)

- A group member may NOT be expelled for any reason
  but may elect not to participate

Forming Groups (continued)

Long term team success is enhanced by team diversity : consider

- –interests and abilities
- –work experience
- –ethnic or cultural attributes
- –gender
- –learning styles
- –marital status , family composition
- –geographical location of residence

Code Of Cooperation (revisited)

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.
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15. Ask questions when you do not understand.
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17. HAVE FUN !!!
18. ?

adapted from the Boeing Airplane Group team Member Training Manual

Some Cooperative Learning Structures and Procedures (7) (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

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)

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)

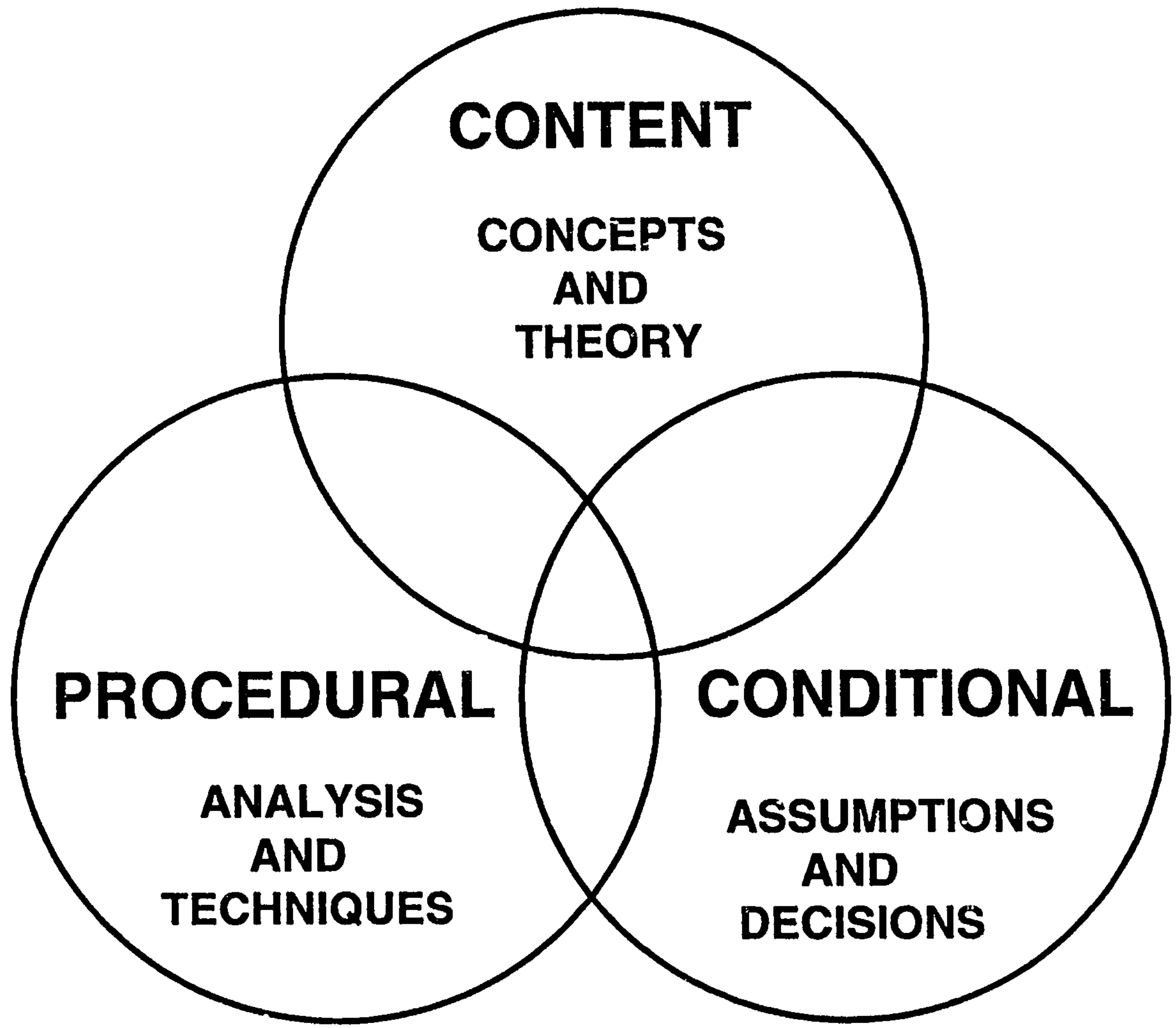
Reflection
(i.e., pause for brief or even extended periods to think about what you have learned and/or the process used to learn; keep an academic journal of your reflections

Hierarchical Structures for Students

Midnight Rider's Hypotheses

- For lower level Engineering Science courses (and topics which are assigned primarily at the Knowledge, Comprehension and Analysis Levels of Learning in any course),
  - it is the responsibility of the teacher to develop and present hierarchical structures for the content.
- A reasonable and appropriate structure, both for the students and for active learning in general,
  - can be deduced from a reflective review of the teacher's original, lecture course notes.

Content, Procedural and Conditional



Knowledge Types (a structure)

The first type of knowledge (first in the sense of the order we choose to discuss it, not in its supremacy to other forms) is *content*. Content knowledge includes physics or basic principles of systems. For example, in a pendulum (as in all real systems) linear and angular momentum, and total energy can be accounted for. To do this, an understanding of what energy and momentum are, as well as an understanding of the forces of gravity and air resistance are needed. This knowledge might be labeled content. The content knowledge in this text will build on fundamentals established in your previous courses. The intent is not to introduce vast amounts of content.

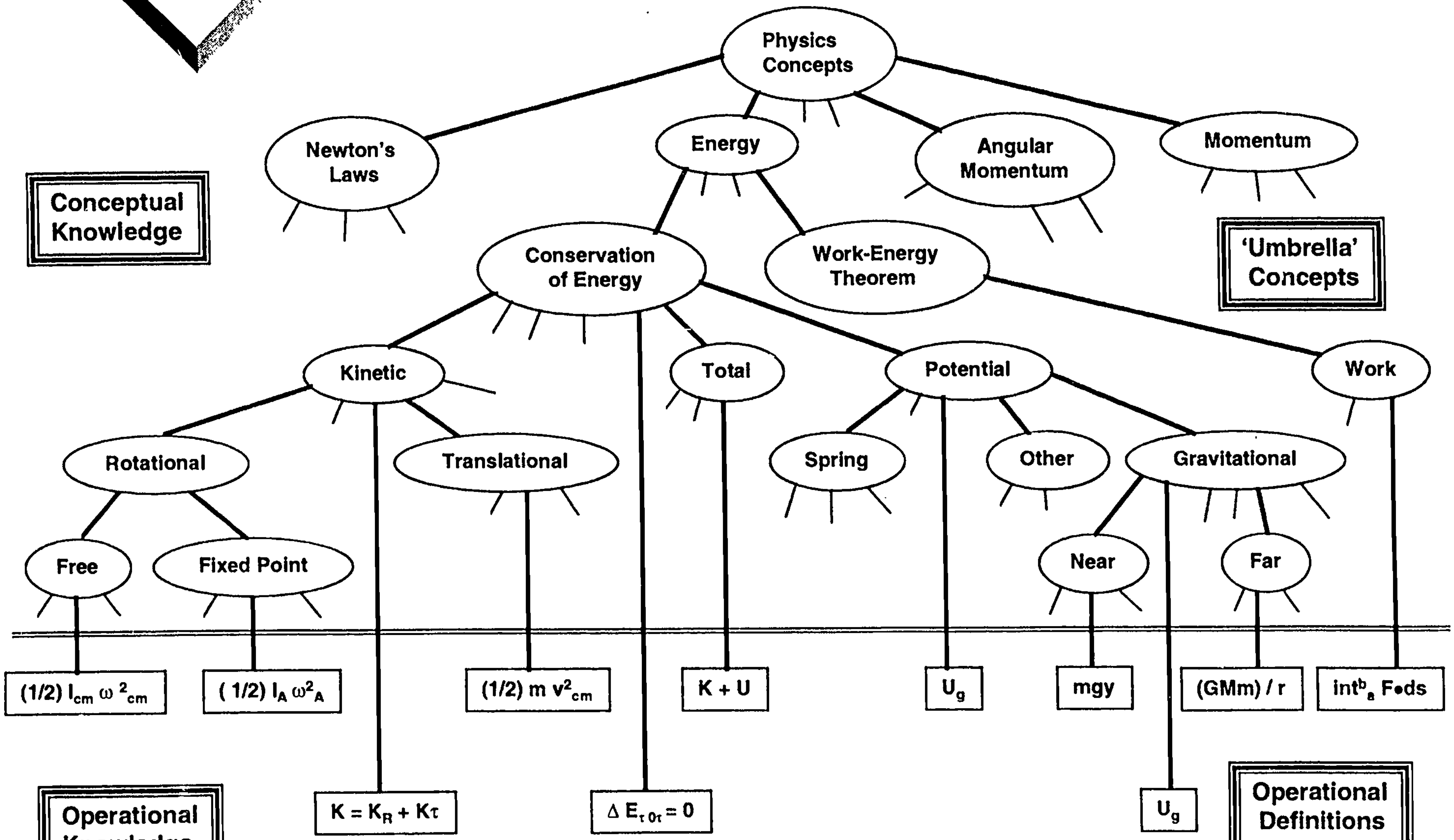
The second, and most common knowledge type in this text, is *procedural*. Procedural knowledge includes the process or methodology which you apply to understand systems. For example, to apply the *content* knowledge that angular momentum is conserved in the pendulum, you must determine the forces acting on the system. This can be done best by drawing a free-body diagram. There is a procedure, or correct way, to draw a free-body diagram, if one does not possess such procedural knowledge it will be difficult to apply content knowledge.

The third type of knowledge contained in this course is *conditional*. Conditional knowledge is used to decide when various methodologies are applicable. For example, if a point on the pendulum is fixed to the Earth, you must decide if the Earth should be assumed fixed, rotating about its axis, or hurling through space.

This course will emphasize te development of procedural and conditional knowledge by providing practice in the design and analysis of complex devices. The objective is to allow you to gain some of the experience necessary to make important engineering decisions about the design and analysis of complex processes. The text will also reinforce knowledge for understanding why a system behaves as it does, and to make design decisions based on desired behavior.

Everett, Louis J.,
Understanding Engineering Systems Via Conservation, 1992, McGraw-Hill, New York

A Hierarchical Structure for Elementary Mechanics[10]



[10] Mestre, Jose P., "Cognitive Aspects of Learning and Teaching Science" [DRAFT], *Pre-College Teacher Enhancement in Science and Mathematics: Status, Issues and Problems*

Standard Format for Engineering Science Homework Problems

NOTE: WORD PROBLEMS TO BE CONVERTED TO MATH NOTATION

* <u>LABELLED</u> <u>SKETCH</u> OF THE <u>SYSTEM</u> AND <u>SURROUNDINGS</u>
(N.B. INCLUDING AN APPROPRIATE COORDINATE SYSTEM)

* <u>SPECIFICATIONS AND DATA</u> : T @ GAS = 100 DEG F (i.e., <u>NOT</u> CONSTANT TEMP.)

[MATH NOTATION] Q @ VESSEL = 0 (i.e., <u>NOT</u> ADIABATIC)

[i.e., DO <u>NOT</u> SIMPLY COPY THE PROBLEM OUT OF THE BOOK.]

- **SPECIFICATIONS** : INFORMATION PROVIDED BY HUMAN BEINGS AND THEREFORE SUBJECT TO CHANGE
- **DATA** : INFORMATION INHERENT IN NATURE AND THEREFORE "INVARIANT"
- **PARAMETERS** : INFORMATION IN WHICH BOTH HUMAN BEINGS AND NATURE HAVE A ROLE IN DETERMINING

* <u>REQUIRED</u> : T @ VESSEL = ?

[MATH NOTATION]

* <u>ASSUMPTIONS</u> (ESSENTIAL) :
1) SYSTEM IS GAS **[MATH NOTATION]**
2) TIME PERIOD 1 HOUR **[WHERE APPROPRIATE]**

NOTE: LEAVE SPACE FOR ASSUMPTIONS AND INSERT THEM AS THEY <u>ARISE</u> <u>DURING</u> YOUR ANALYSIS PROCESS.

* <u>ANALYSIS</u> : <u>NEAT</u> <u>NEAT</u> <u>NEAT</u>

* T @ VESSEL	=	87.3 DEG F	<u>WITH</u> <u>UNITS</u>! <u>IN</u> <u>A</u> <u>BOX</u>!

* <u>REFLECTIONS</u> : A BRIEF DISCUSSION OF OBSERVATIONS AND CONCLUSIONS DERIVED FROM THIS PROBLEM (WHAT WAS LEARNED?)

CONSERVATION PRINCIPLES IN ENGINEERING, ECE 394A

PARTICLE DYNAMICS OR KINETICS (BOTH SIDES !)

N.B. The **PARTICLE** is the **system** (or 'free body')

N.B. Linear momentum and mechanical energy are <u>NOT</u> <u>IN</u>**DEPENDENT** for **particles** or **RIGID BODIES** !

---

* **LINEAR MOMENTUM**

IN/OUT BY FLOW	+	IN/OUT BY <u>EXTERNAL</u> FORCES	=	ACCUMULATION
(N)		(N)		(N)

$$0 \quad + \quad \sum \underset{\sim}{f}_{EXTERNAL} \quad = \quad m_{SYS} \frac{d}{dt}\left(v_G \right) \quad = \quad m\, a_G$$

N.B. Constant mass system ; no flow in or out !

- Coordinate system , position vectors , unit vectors changing with time , time period?

---

* **MECHANICAL ENERGY**

IN/OUT BY FLOW	+	IN/OUT BY <u>EXTERNAL</u> FORCE	=	ACCUMULATION
(E/t)		(POWER, E/t)		(E/t)

$$0 \quad + \quad \sum \dot{W} \quad = \quad m_{SYS} \frac{d}{dt} \left(\hat{E}_K + \hat{E}_P \right)_{SYS}$$

N.B. Constant mass system ; no flow in or out !

- Coordinate system , position vectors , unit vectors changing with time , time period?

QUESTION : Would inelastic collisions change the unsteady state accounting for mechanical energy ? If so, how ? If not, why not?

QUESTION : Would the unsteady state accounting for mechanical energy be useful in solving the trajectory problem with air resistance (i.e., drag)? Explain.

Structure :

- Display the essential features of the problem in a labelled sketch. Include an appropriate coordinate system.
- What is the desired behavior? Are you to 'predict' or 'design'?
- Identify an appropriate system(s).
- What extensive properties are to be accounted for or conserved?
- What is an appropriate time period?
- State the applicable balances in tabular form.
- Delineate the specifications, data, and "defining relationships".
- Make appropriate assumptions, if necessary, and quantify the behavior.

Task :

- A 80 kG track star is attempting to "do a cannon ball" into the swimming pool from the second story roof of an apartment complex.
- The friction and form drag force exerted on a "ball" at low velocities may be approximated by:

$$k_D \, v \qquad \text{where} \qquad k_D = 30 \; (\, kG \,/\, S \,)$$

- The star runs the 200 M dash in 25 S.
- How far can the edge of the pool be from the apartment for the star to land "safely" ?
- What is the magnitude of the final velocity of the star on impact ?
- How long does the star remain in flight ?

Individual Accountability Check Sheet

Team #	A	B	C	D	E
1	GUITEIRREZ	JOHNSON	JORDAN	JUETTEN	LAMMERS
2	BARUTHA	HAAS	LEET	ROLAND	SADAKA
3	BAUTISTA	DOWNS	RICHARDS	ROALOFS	
4	MCEUEN	PATEL	THORNE	WILEY	
5	BINDRIM	SURASIT	GIAMALVA	HILL	
6	CAPRIOLA	FENNEL	PINDER	TSUCHIMOTO	
7	ABDULLAH	ALMURSHED	AMDERSON	MORITZ	
8	CHIN	DOBSON	KAHN	VOIGTS	
9	CLARK	DESCAMPS	FUENTALBA	PETRAMALA	

Evaluation Revisited

- Good student evaluation practices can:
  - reduce undesired competition
  - foster cooperation
  - foster life long learning
  - revive intrinsic motivation for learning
  - drive out fear from the class room

Principles of Good Practice for Assessing Student Learning (1)

1. The assessment of student learning begins with educational values.
2. Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated, and revealed in performance over time.
3. Assessment works best when the programs it seeks to improve have clear, explicitly stated purposes.
4. Assessment requires attention to outcomes but also and equally to the experiences that lead to those outcomes.
5. Assessment works best when it is ongoing, not episodic.
6. Assessment fosters wider improvement when representatives from across the educational community are involved.
7. Assessment makes a difference when it begins with issues of use and illuminates questions that people really care about.
8. Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change.

Student Assessment Using a Competency Matrix

- Students evaluate their own progress in passing through the various stages of learning.
- When a student has material in her/his portfolio which demonstrates competency at a certain level of learning for some concept, the student enters the location (e.g., page number of reflection log) of the material on the evaluation matrix in the appropriate box.
- Students keep a portfolio of homework, tests, quizzes, projects, reports, etc.
- Reflection entries and work logs also constitute a significant contribution to a portfolio
- Competency matrices and portfolios are periodically collected and checked by the instructor (or other students in class).

Grades and the Matrix

- Mark the assumed initial state of learning for each concept shown in the matrix
- Mark the state of learning which follow-on classes assume all students will have reached having taken this class. This corresponds to a grade of B for example (i.e., the average grade in Engineering at ASU)
- Higher grades (i.e., A) correspond to higher states of learning in some or all of the concepts (pre-specified!)
- The A grade should be obtainable by all intrinsically motivated students

Appendix

- ***Partial Bibliography***
- ***Notes on Change in the Learning Environment***
  - *Adaptability*
  - *Accomodation*
  - *Emphasis*
  - *Engineering: In School and Out*
  - *Restructuring*
  - *Seven Styles of Learning (one example)*
- ***Notes on the Process of Change***

  (Stages of Concern, Conclusions, Cautions, Intervention Stratagies)
- ***Some Interesting Data from the K - 12 System***

  (What is Taught vs. What is Learned , Self-Esteem vs. Grade Level)
- ***David Langford / Barry McNeill Levels of Learning***

Partial Bibliography

1 American Association for Higher Education, Assessment Forum, 1992.

2 Chickering, A.W. & Gamson, S.F., Seven Principles for Good Practice in Undergraduate Education, Wingspread Journal 9(2), 1987.

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5 Kagan, Spencer, Cooperative Learning: Resources for Teachers, San Juan Capistrano, CA: Resources for Teachers, 1990.

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11 Gardner, Howard, *The* Unschooled Mind; How Children Think and How Schools Should Teach, 1991, Basic Books

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

Adaptability *

Engineering Careers in the '90s :

Adaptability is the watchword. The Department of Labor tells professionals to expect a lot of change. A new college graduate can expect to work 48 years in five careers and 12 jobs. Self-reliance, constant training, and flexibility are the keys to staying employed. Be ready to make lateral moves to build new skills. The only security is in your skills, experiences and successes.

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

Accomodation *

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).

And 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 ....

* Norman, Don A. (1980), 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

Emphasis

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.

Albert Einstein

Engineering: In School and Out

Engineering schools recognize the overlap in industry between engineering and science, and they design their curricula accordingly. Engineering education is strongly theoretical and geared toward math and science. This is partly because of the natural interests of people who are attracted to a professorial life and who set the curriculum. It is also because 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. But because the activities of the engineering student have little relation to the activities of many practicing engineers, it is likely that engineering education discourages some students who would make excellent engineers and encourages others who will not. The mentality to do well in engineering schools emphasizes the ability to work problem sets and get right answers. In engineering, there are never right answers and few problem sets.

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

Restructuring

These problems are endemic to all institutions of education, regardless of level. Children 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.

Fosnot, C.T. (1989). Enquiring Teachers, Enquiring Learners. NY: Teachers College Press.

Seven Styles of Learning [11]

TYPE	LIKES TO	IS GOOD AT	LEARNS BEST BY
LINGUISTIC LEARNER "The Word Player"	read write tell stories	memorizing names, places, dates and trivia	saying, hearing and seeing words
LOGICAL/ MATHEMATICAL LEARNER "The Questioner"	do experiments figure things out work with numbers ask questions explore patterns and relationships	math reasoning logic problem solving	categorizing classifying working with abstract patterns/relationships
SPATIAL LEARNER "The Visualizer"	draw, build, design and create things daydream look at pictures/slides watch movies play with machines	imagining things sensing changes mazes/puzzles reading maps, charts	visualizing dreaming using the mind's eye working with colors / pictures
MUSICAL LEARNER "The Music Lover"	sing, hum tunes listen to music play an instrument respond to music	picking up sounds remembering melodies noticing pitches / rhythms keeping time	rhythm melody music
BODILY/KINESTHETIC LEARNER "The Mover"	move around touch and talk use body language	physical activities (sports/dance/acting) crafts	touching moving interacting with space processing knowledge through bodily sensations
INTERPERSONAL LEARNER "The Socializer"	have lots of friends talk to people join groups	understanding people leading others organizing communicating manipulating mediating conflicts	sharing comparing relating cooperating interviewing
INTRAPERSONAL LEARNER "The Individual"	work alone pursue own interests	understanding self focusing inward on feelings / dreams following instincts pursuing interests/goals being original	working alone individualized projects self-paced instruction having own space

[11] Based on material presented in Howard Gardner's *The Unschooled Mind; How Children Think and How Schools Should Teach.* Basic Books, 1991.

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 <u>actively</u> 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.)

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 him/her and job.

④ People go through phases, or stages, when trying to adopt a change.

⑤ Stages can be predicted and planned for.

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.

Intervention Strategies for Change *

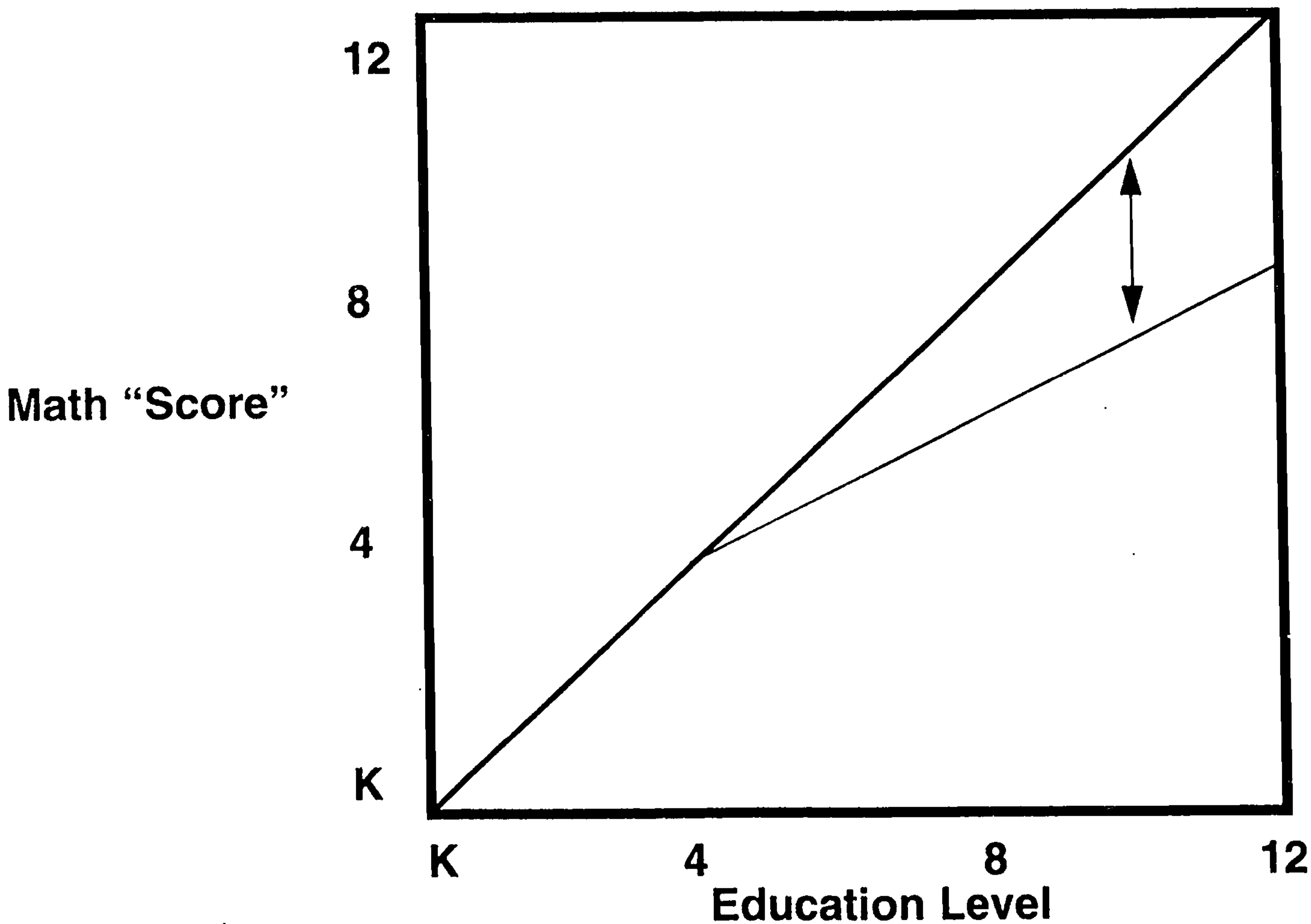
1. What kinds of support (interventions) might enable a person to move from one stage to the next?

2. What support, activities, or interventions exist at this institution that might help people in the stages previously discussed.

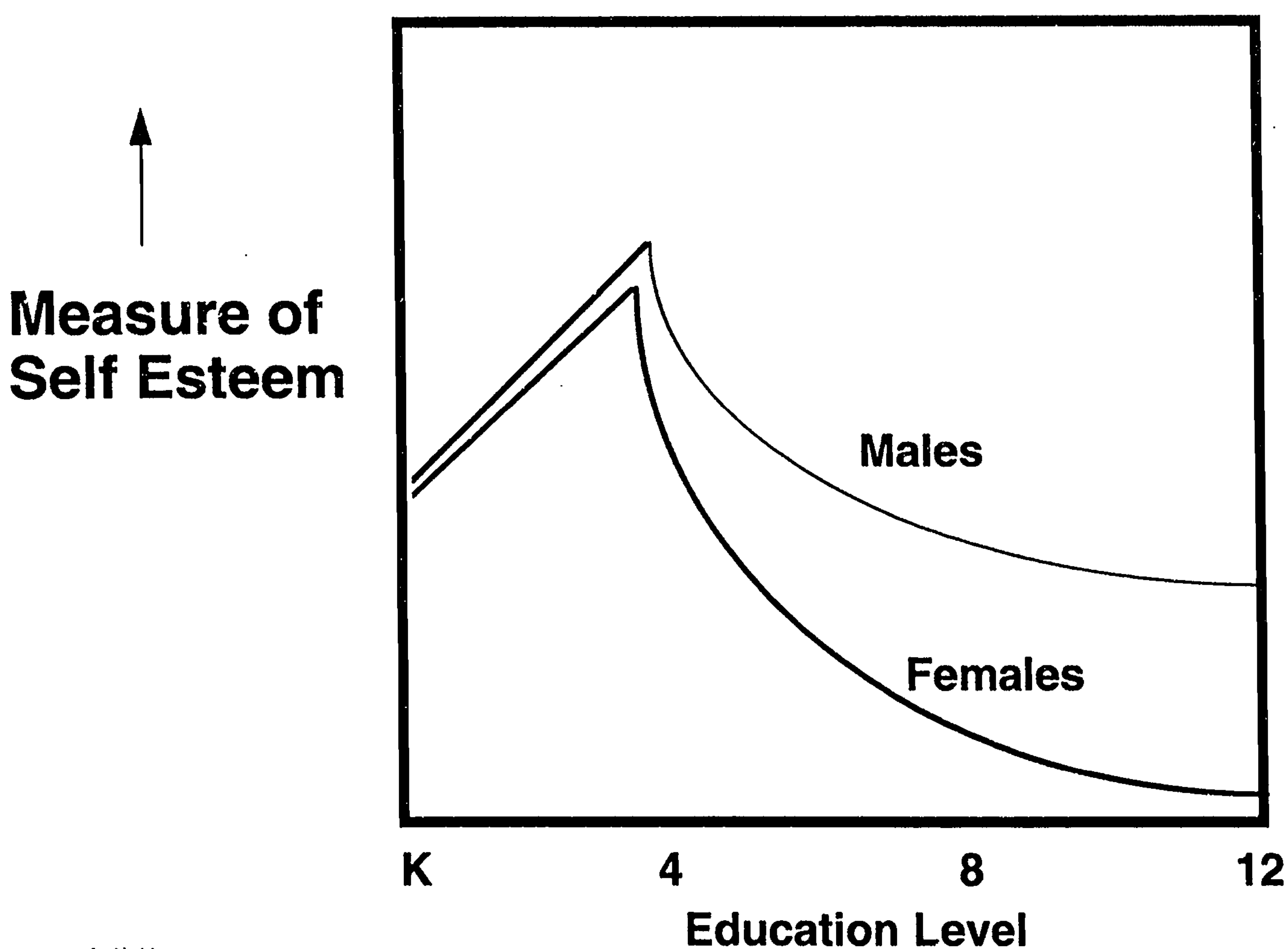
* Hall, G.E. & Hord, S.M. (1987), Change in Schools: Facilitating the Process, Albany, NY, State Univeristy of New York Press

Disparity Between What is Taught and What is Learned

(NAEP mathematics report 1990 and Iowa Test scores)



Self-Esteem vs. Education Level



Knowledge (Information)

Process verbs:		
define	memorize	record
label	name	relate
list	read	repeat
listen	recall	view

How do I know I have reached this level?
I recall information? I bring to mind the appropriate material at the appropriate time? I have been exposed to the information and I can respond to questions, tasks, etc.

What do I do at this level?
I read material, listen to lectures, watch videos, take notes and I am able to pass a test of knowledge on the subject area. I learn the vocabulary of the competency area, i.e., the terminology. I learn the conventions used.

How will the teacher know I am at this level?
The teacher will provide opportunities (either orally or in written tests), regardless of complexity, that can be answered through simple recall of previously learned material.

What does the teacher do at this level?
The teacher directs, tells, shows, identifies, examines the information necessary at this level.

What are typical ways I can demonstrate my knowledge?
1. Define technical terms by giving their attributes, properties or relations.
2. Recall the major facts about a particular subject.
3. List the characteristic ways of treating and presenting ideas (i.e., list conventions associated with the subject).
4. Name the classes, sets, divisions, and arrangements
   which are regarded as fundamental for a given subject field or problem.
5. List the criteria used to judge facts, principles, and ideas.
6. Describe the method(s) of inquiry or techniques and procedures used in a particular field of study.
7. List the relevant principles and generalizations.
8. Fill in the blank.

Modifications by B. McNeill of David 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.

Comprehension / Understanding

Process verbs:			
describe	identify	report	tell
explain	locate	restate	work
express	recognize	review	

<u>How do I know I have reached this level?</u>
I comprehend and understand what is being communicated and make use of the ideas but without relating them to other ideas or material. I may not yet understand the fullest meaning. I understand what others are discussing concerning this idea. This level requires Knowledge.

<u>What do I do at this level?</u>
I successfully work assignments in which the appropriate approach is evident either because of material in the problem statement or because of the problem's relative location in the book to the appropriate method. I translate information into my own words (translation from one level of abstraction to another. I translate symbolic information (e.g., tables, commas, diagrams, graphs, mathematical formulas, etc.) into verbal forms, and vice versa. I interpret or summarize communications (written/graphical/oral). I determine implications, consequences, corollaries , effects, etc. which are extensions of trends or tendencies beyond the given data.

<u>How will the teacher know I am at this level?</u>
The teacher will often ask questions or give tests that can be answered by merely restating or reorganizing material in a rather literal (clearly stating the facts or primary meaning of the material) manner to show that I understand the essential meaning, e.g., give the ideas in your own words.

<u>What does the teacher do at this level?</u>
The teacher demonstrates, works problems, listens, questions, compares, contrasts, and examines the information and your knowledge of it.

<u>What are typical ways I can demonstrate or can show on my own my comprehension and understanding.</u>
1. Read Comprehension level problems, know what is being asked for, and successfully work the problems.
2. Clearly chronicle the process used in working the problem.
3. Clearly describe the results of working the problem.
4. Draw conclusions (interpret trends) from the results of solving the problem.
5. Compare/contrast two different problems (i.e., what things are the same? / what things are different?)
6. Restate and idea, theory, or principle in your own words.

Modifications by B. McNeill of David 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.

Application (Thinking)

Process verbs:		
apply	illustrate	practice
demonstrate	interpret	recognize
employ	operate	

How do I know I have reached this level?

I have the ability to recognize the need to use an idea, method, concept, principle, or theory without being told to use it, i.e., I have the ability to use ideas, methods, concepts, principles and theories in new situations. I know and comprehend the information and can apply it to a new situation. I also have the ability to recognize when a certain task, project, theory or concept is beyond my current competency. Application requires having Knowledge and Comprehension.

What do I do at this level?

I work problems for which the solution method is not immediately evident or obvious. I take knowledge that has been learned at the Knowledge and Comprehension levels of learning and apply it to new situation. I solve problems on my own and make use of other techniques. This requires not only knowing and comprehending information, but deep thinking about the usefulness of this information and how it can be used to solve new problems that I create or identify.

How will the teacher know I am at this level?

I will show the teacher through my work that I am involved in problem solving in new situations with minimal identification or prompting of the appropriate rules, principles, or concepts by the teacher. The teacher will be able to ask general questions like, How much protection from the sun is enough? and I will know how to attack the problem.

What are the typical ways I can demonstrate or show, on my own, my application of Knowledge and Comprehension?

1. Solve problems which require recognition of the appropriate concepts, theories, solution techniques, etc.
2. Apply the laws of mathematics, chemistry, physics, and engineering to practical situations.
3. Work *project type* problems.

Modifications by B. McNeill of David 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.

Analysis (Thinking)

Process verbs:	
break apart	examine
break down	explain

How do I know I have reached this level?
I can explain *why*. I can examine, methodically, ideas, concepts, writing etc. and separate into parts or basic principles. I have the ability to break down information into component parts in order to make organization of the whole clear. Work at this level requires having Knowledge and Comprehension levels of learning (application is not required).

What do I do at this level?
I analyze results by breaking concepts, ideas, theories, equations, etc. apart. I can explain the logical interconnections of the parts and can develop detailed cause and effect chains.

What does the teacher do at this level?
The teacher probes, guides, observes, and acts as a resource.

What are typical questions I can pose for myself to answer which will demonstrate or show my Analysis level of learning?
1. Why did this (result) happen?
2. What reasons does she give for her conclusions?
3. Does the evidence given support the hypothesis, the conclusion?
4. Are the conclusions supported by facts, opinions, or analysis of the results?
5. What are the causal relationships between the results for the whole and the parts?
6. What are the unstated assumptions?

Modifications by B. McNeill of David 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.

Synthesis (Thinking)

Process verbs:			
arrange	construct	manage	propose
assemble	create	organize	set up
collect	design	plan	write
compose	formulate	prepare	

<u>How do I know I have reached this level?</u>
I have the ability to put together parts and elements into a unified organization or whole which requires original, creative thinking. I recognize new problems and develop new tools to solve them. I create my own plans, models, and/or hypotheses for finding solutions to problems. This level of learning requires Knowledge, Comprehension, Application and Analysis levels of learning.

<u>What do I do at this level?</u>
put ideas together to create something. This could be a physical object, a process, a design method, a communication, or even a set of abstract relations (i.e., mathematical models). I produce reports, (written/oral) which create a desired effect (e.g., information acquisition, acceptance of a point of view, continued support, etc.) in the reader (listener). I generate project plans, I propose designs, I formulate hypotheses based on the analysis of pertinent factors. I am able to generalize from a set of axioms, principles.

<u>How will the teacher know I am at this level?</u>
I show that I can combine ideas into a statement, plan, product, etc. that is new for me; e.g., I can develop a program that includes the best parts of each of those ideas

<u>What does the teacher do as this level?</u>
The teacher reflects, extends, analyses, and evaluates.

<u>What are the typical questions I can answer which will demonstrate or show my Synthesis?</u>
1. Can I create a project plan?
2. Can I develop a model?
3. Can I propose a design?

Modifications by B. McNeill of David 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.

Appreciation/Evaluation (Wisdom)

Process verbs:	
appraise	judge
choose	predict (quality)
compare	rate value
estimate (quality)	select
evaluate	

How do I know I have reached this level?
I have the ability to judge and appreciate the value of ideas, procedures and methods using appropriate criteria. To work at this level requires having achieved Knowledge, Comprehension, Application, Analysis and Synthesis levels of learning.

What do I do at this level?
I make value judgments based on certain considerations such as usefulness, effectiveness, and so on. 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 planned work. I evaluate work based on internal standards of consistency, logical accuracy and the absence of internal flaws (e.g., I can certify if design feasibility has been demonstrated in a report). I evaluate work based on external standards of efficiency, cost, utility to meet particular ends (e.g., I can certify that design quality has been demonstrated in a report).

How will the teacher know I am at this level?
I can demonstrate that I can make a judgment about something using some criteria or standard for making the judgment.

What does the teacher do at this level?
The teacher clarifies, accepts, harmonizes, aligns, and guides.

What are typical statements and questions I can respond to which 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 i.e., modeling approaches is the best for my current needs. How does this report show that the design is feasible? How does this report show the quality of the design?

Modifications by B. McNeill of David 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.

Affective (Character) Traits

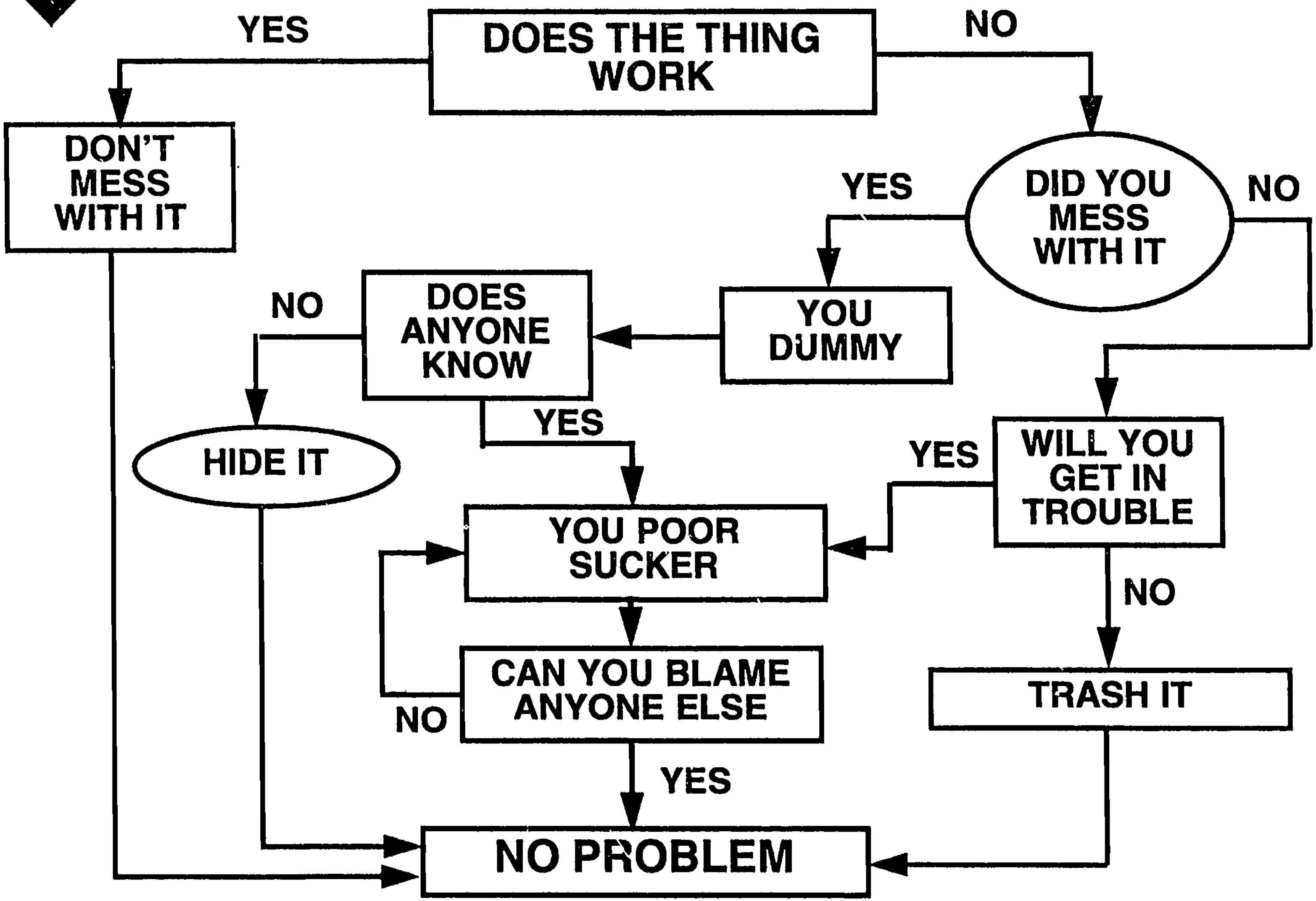
What are some affective traits?

Ability to work alone	Curiosity	Interest
Ability to work in teams	Honesty	Self Esteem
Attention	Initiative	Truthfulness
Cooperativeness	Integrity	

What questions can I ask myself to determine if I am exhibiting these characteristics?

1. Do I come to class (meetings) prepared?
2. Do I come to class (meetings) on time?
3. Do I seek out material on a subject beyond what is suggested by the instructor?
4. Do I admit when I do not know something?
5. Do I talk about class subjects with my friends during informal gatherings.
6. Do I help others when they are having difficulties?
7. Do I invest the time expected working on the class (meetings)?
8. Do I do the work I say I will do and have it done when I say I will have it done?
9. Do I know I can solve problems?

Problem Solving Flowsheet



Structure for the Systems Course

- Conservation Principles Course Objectives — 1 pps.
- Engineering Systems Via Conservation
  - Course Objectives — 1 pps.
  - Active Learning Procedure — 2 pps.
  - An Example of the Procedure — 4 pps.
  - Another Example of the Procedure — 6 pps.
- Demings Fourteen Points (revised by students) — 2 pps.
- Active Learning Example from Calculus
  - The Definite Integral (PROMPT) — 1 pps.
  - Structure for the Task — 1 pps.
  - Task (example problem) — 1 pps.

CONSERVATION PRINCIPLES IN ENGINEERING, ECE 394A

COURSE OBJECTIVES

By the end of this course, the student should be able to:

1. list the physical quantities that are conserved and those that can be accounted for;

2. state the general conservation laws for those properties that are conserved and state the general accounting balances for the properties which are not conserved.

3. For a specific engineering problem:

   a. identify an appropriate system, surroundings and time period based on a verbal or written description of the problem or a visual observation of the physical system;

   b. identify the quantities to be conserved and those that can be accounted for in the system and surroundings;

   c. construct the appropriate conservation laws and accounting balances;

   d. delineate the specifications and data required for the model if the number of independent equations is to equal the number of unknowns;

   e. make appropriate assumptions, but retain the important elements of the problem;

   f. state whether the model is descriptive or predictive;

   g. solve the resulting equations which describe the model;

   h. discuss the physical relevance of the numerical values for the solution and the physical relevance of the problem in general;

   i. state the distinction between the mathematical model and the physical reality the model attempts to describe;

In addition, the student should:

4. develop a cooperative attitude towards learning;

5. take an active role in her or his education;

6. strive for continuous improvement.

UNDERSTANDING ENGINEERING SYSTEMS
VIA CONSERVATION, ECE 394C

COURSE OBJECTIVES

By the end of this course, the student should be able to:

1. Differentiate between the three types of knowledge: content, procedural, and conditional.
2. Demonstrate the ability to make important engineering decisions about the design and analysis of complex processes.
3. Model multidiscipline and highly complex single discipline systems.
4. Differentiate between symptoms of a "problem" and the root cause of a "problem".
5. Model vs. reality.
6. Reading and interpreting a problem by extracting important information and ignoring unimportant details.
7. Demonstrate the ability to understand systems as opposed to solving problems.
8. Properly execute thoughts and ideas.
9. Determine system extent.

RECOMMENDED PROCEDURE

1 **Understand** the System and **Define** the State of the System

- Prepare a Labeled **SKETCH**

- Determine the **MODEL DEGREES OF FREEDOM**

  List the **Possible** Flows or Motions
  (i.e., based on the labeled sketch)

  Which Flows or Motions are **Relevant**?
  (INCLUDE the concomitant CONDITIONS)

  Which Flows or Motions are **Independent**?
  (INCLUDE the concomitant CONDITIONS)

- Determine the **SYSTEM EXTENT** (e.g., Freebody Diagram)

- Is the **MODEL** to be used to **Design** or to **Predict** Behavior?

  List the Appropriate **MODEL**

  Data, Specifications, and Parameters

- Determine the **Order** of the **MODEL** of the System

  List the **POSSIBLE** Accumulation or State Variables

  Which Accumulations are **Relevant**

  Which Accumulations are **Independent**?
  (INCLUDE concomitant CONDITIONS)

- Predict the **MINIMUM** Number of

  Auxiliary Variables or Algebraic Equations (**if DOF>ORDER**)

2 Develop a **Mathematical MODEL of the System**

- Formulate the Conservation and Accounting Balances

- Formulate One or More Sets of Independent, First Order Differential Equations for the **MODEL**

- Formulate the Intuitively Obvious **Constraints**, (INCLUDING the 'Defining Relationships', IF ANY!)

- List **ALL** of the **MODEL** Variables (i.e., **NOT** just the Unknowns!)

- Determine if the **MODEL** is Complete and Solvable

  Perform the Analysis of the Mathematical Model

	Variables	
-	Equations	
-	Data	(List Variables)
-	Specifications	(List Variables)
-	Parameters	(List Variables)
-	Initial conditions	(List Variables)
=	Unknowns	

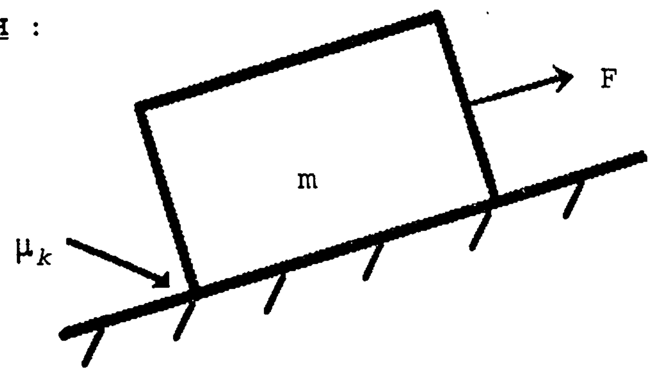
  List the Unknowns and Identify the Result Variables
  (N.B. The number of result variable should equal the number of equations)

- Select Values for the Appropriate Set of Variables and Quantify the System Behavior or Response

- Document the Solution.
  N.B. Include the Procedural and Conditional Information used in the model (e.g., vector loops) which will be of value in preparing entries for the Competency Matrix.

AN EXAMPLE OF THE PROCEDURE

SKETCH :



$v_0 \neq 0$

AT

$t = 0$

(i.e., it's moving !)

POSSIBLE DOF (Flows or Motions)

1. Motion **PARALLEL** to the incline (up or down)
2. Rotational motion (i.e., it 'tips')
3. Motion **PERPENDICULAR** to the incline (i.e., rotation causes the center of gravity to move vertically)
4. Thermal energy flow due to friction

RELEVANT FLOWS OR MOTIONS

1. Motion **PARALLEL** to the incline

   Conditions :

   * Assume the block does **NOT** rotate; therefore it does **NOT** move vertically
   * Neglect thermal energy effects

INDEPENDENT FLOWS OR MOTIONS

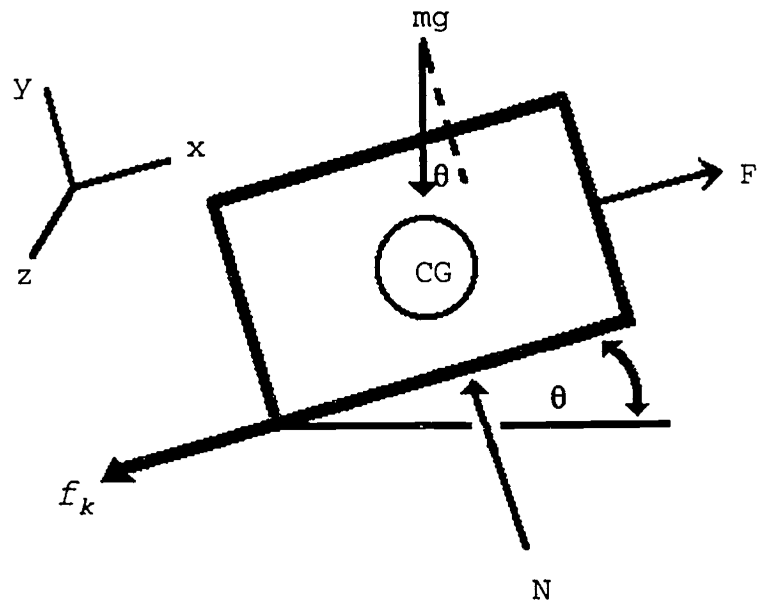
1. Motion **PARALLEL** to the incline

   Conditions :

   * None

ACTUAL DOF : 1

SYSTEM EXTENT :



PREDICT THE BEHAVIOR

What is the motion of the block if the applied force is constant?

Data : **g**

Specifications : **F , m , θ**

Parameters : μ_k

ORDER :

POSSIBLE ACCUMULATIONS

1. Linear Momentum (LM) **PARALLEL** to the Incline
2. Kinetic Energy (KE) due to Linear Motion
3. Gravitational Potential Energy (GPE)

INDEPENDENT ACCUMULATIONS

1. LM or KE (State Variable , *V*)
2. GPE (State Variable , **h**)

CONDITIONS :

* LB and KE can both be determined from the linear velocity

AUXILLARY VARIABLES

DOF - ORDER = 1 - 2 = -1 , NO INFORMATION

MATHEMATICAL MODEL

* CONSERVATION AND ACCOUNTING EQUATIONS

$\boxed{1}$ $$F - f_k - mg\,SIN\,\theta = \frac{d}{dt}(mv)$$

* OTHER FIRST ORDER ODE's

$\boxed{2}$ $$v = \frac{dx}{dt}$$ (N.B. Also a Constraint !)

* CONSTRAINTS

$\boxed{3}$ $$f_k = \mu_k N$$

$\boxed{4}$ $$N - mg\,COS\,\theta = 0 \quad ; \quad N \prec 0$$

N.B. The block must be in contact with the incline or there is no friction and no frictional force.

MODEL VARIABLES

* EQUATION $\boxed{1}$

9 : F , f_k , m , g , θ , v , v_o , t , t_o

* EQUATION $\boxed{2}$

2 : x , x_o

* EQUATION $\boxed{3}$

2 : μ_k , N

* EQUATION $\boxed{4}$

0 : NO ADDITIONAL VARIABLES

* TOTAL 9 + 2 + 2 + 0 = $\boxed{13}$

ANALYSIS

13 VARIABLES

\- 4 EQUATIONS

---

9 UNKNOWNS

\- 1 DATA (g)

\- 3 SPECIFICATIONS (F , m , θ)

\- 1 PARAMETER (μ_k)

\- 3 INITIAL CONDITIONS (x_o , v_o , t_o

NET + 1 (OK , t is the independent variable !)

UNKNOWNS

1. $v(t)$
2. $x(t)$
3. N
4. f_k
5. t (the independent variable)

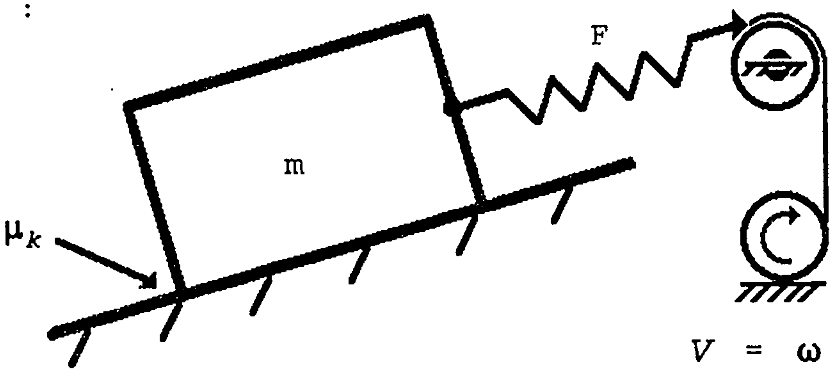
THE NUMBER OF RESULT VARIABLES EQUALS THE NUMBER OF EQUATIONS

N.B. The value of one o' these variables must be specified since there are only 4 equations.

NOTE : If the independent variable t is **NOT** specified, the solution process may require a trial and error process.

ANOTHER EXAMPLE OF THE PROCEDURE

SKETCH :



$v_0 \neq 0$

AT

$t = 0$

(i.e., it's moving !)

$V = \omega R$

POSSIBLE DOF (Flows or Motions)

1. Motion of the block **PARALLEL** to the incline (up or down)
2. Rotational motion of the block (i.e., it 'tips')
3. Motion of the block **PERPENDICULAR** to the incline
   (i.e., rotation causes the center of gravity to move vertically)
4. Thermal energy flow due to friction between the block and incline
5. Motion of the spring **PARALLEL** to the incline

RELEVANT FLOWS OR MOTIONS

1. Motion of the block **PARALLEL** to the incline
2. Motion of the spring **PARALLEL** to the incline

   Conditions :

   * Assume the block does **NOT** rotate;
     therefore it does **NOT** move vertically
   * Neglect thermal energy effects

INDEPENDENT FLOWS OR MOTIONS

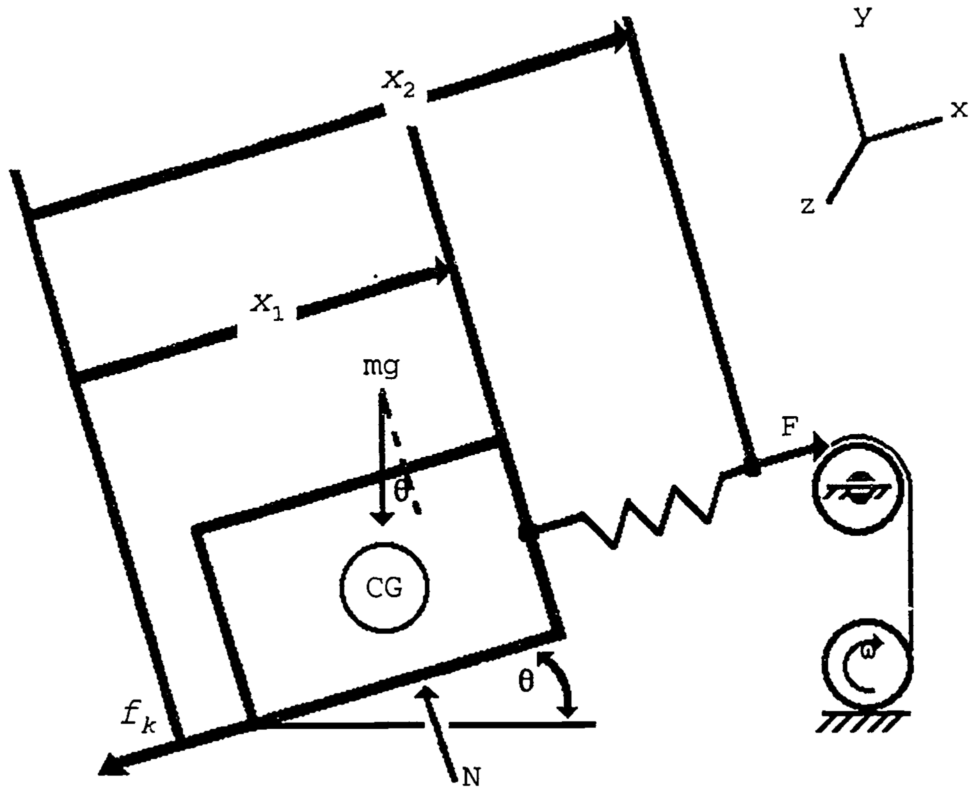
1. Motion of the block **PARALLEL** to the incline
2. Motion of the spring **PARALLEL** to the incline

   Conditions :

   * None (N.B. hold the right end of the spring AND hold the block)

ACTUAL DOF : 2

SYSTEM EXTENT :



PREDICT THE BEHAVIOR

What is the motion of the block if the winch velocity is constant?

DATA : **g** ; SPECIFICATIONS : **m , θ , v** ; PARAMETERS : μ_k , k

ORDER :

POSSIBLE ACCUMULATIONS

1. Linear Momentum (LM) of the block **PARALLEL** to the Incline
2. Kinetic Energy (KE) of the block due to Linear Motion
3. Gravitational Potential Energy (GPE) of the block
4. Spring Potential Energy (SPE)

RELEVANT, INDEPENDENT ACCUMULATIONS

1. LM or KE of the block (State Variable , v)
2. GPE of the block (State Variable , **h**)
3. SPE (state variable, $x_2 - x_1 - l$)

CONDITIONS :

* LM and KE can both be determined from the linear velocity

AUXILLARY VARIABLES

DOF - ORDER = 2 - 3 = -1 , NO INFORMATION

MATHEMATICAL MODEL

$$\dot{m} = 0 \quad ; \quad \Sigma \dot{Q} = 0 \quad ; \quad \frac{dU}{dt} = 0$$

$$\Sigma \dot{W} - \Sigma \dot{F} = \frac{d}{dt} (KE + PE)$$ **N.B. BOTH GPE AND SPE**

* CONSERVATION AND ACCOUNTING EQUATIONS

$\boxed{1}$ $F V - f_k v =$

$$\frac{d}{dt} \left\{ m \left(\overbrace{\frac{v^2}{2}}^{\hat{KE}_B} + \overbrace{g x_1 SIN\theta}^{G\hat{PE}_B} \right) + \overbrace{\frac{k}{2} \left[(x_2 - x_1 - l)^2 - (\underbrace{x_{20} - x_{10}}_{constants} - l)^2 \right]}^{PE_{SPRING}} \right\}$$

* OTHER FIRST ORDER ODE's (N.B. THIRD ORDER !)

$\boxed{2}$ $v = \frac{dx_1}{dt}$ (N.B. ALSO A CONSTRAINT !)

$\boxed{3}$ $V = \frac{dx_2}{dt}$ (N.B. ALSO A CONSTRAINT !)

* CONSTRAINTS (INCLUDING "DEFINING RELATIONSHIPS"

$\boxed{4}$ $f_k = \mu_k N$ (N.B. Also a Constraint !)

$\boxed{5}$ $N - mg\, COS\, \theta = 0$

N.B. The block must be in contact with the incline or there is no friction and no frictional force.

MODEL VARIABLES

* EQUATION $\boxed{1}$

15 : F , V , f_k , v , $\overset{(IC)}{v_o}$, m , g , x_1 , θ , k , x_2 , $\overset{(IC's)}{x_{20} , x_{10}}$, t , $\overset{(IC)}{t_o}$

* EQUATION $\boxed{2}$

0 :

* EQUATION $\boxed{3}$

0 :

* EQUATION $\boxed{4}$

2 : μ_k , N

* EQUATION $\boxed{5}$

0 :

* TOTAL 15 + 0 + 0 + 2 = $\boxed{17}$

ANALYSIS

17 VARIABLES

\- 5 EQUATIONS

\- 1 DATA (g)

\- 3 SPECIFICATIONS (m , θ , v)

\- 2 PARAMETERS (μ_k , k)

\- 4 INITIAL CONDITIONS (v_o , x_{20} , x_{10}) t_o

---

2 UNKNOWNS (1 OF WHICH IS t)

N.B. REMEMBER t IS THE INDEPENDENT VARIABLE !

CONCLUSION : SEARCH FOR MORE EQUATIONS !

MATHEMATICAL MODEL (CONTINUED)

* BLOCK LM , SPRING "DEFINING RELATIONSHIP" ?
* CONSERVATION AND ACCOUNTING EQUATIONS

$$\boxed{6} \quad F - f_k = \frac{d}{dt}(mv)$$

* CONSTRAINTS (INCLUDING "DEFINING RELATIONSHIPS")

$$\boxed{7} \quad F = -k\,[\,(x_2 - x_1) - l\,]$$ (N.B. Also a Constraint !)

ANALYSIS (CONTINUED)

2 VARIABLES (FROM PREVIOUS PAGE)

\+ 1 PARAMETER (l FROM $\boxed{7}$)

3

\- 2 EQUATIONS ($\boxed{6}$ AND $\boxed{7}$)

\- 1 PARAMETER (l)

---

0 **NOT** OK , t IS THE INDEPENDENT VARIABLE !

N.B. THEREFORE **1** OF THE $\boxed{7}$ EQUATIONS IS DEPENDENT

NOTE THE FOLLOWING RELATIONSHIPS !

1. $\frac{d}{dt}(TE_{SYSTEM}) = \frac{d}{dt}(ME_{BLOCK}) + \frac{d}{dt}(PE_{SPRING})$

2. $\frac{d}{dt}(ME_{BLOCK}) = v \cdot \frac{d}{dt}(LM_{BLOCK}) + \frac{d}{dt}(GPE_{BLOCK})$

3. $F \cdot (V - v) = \frac{d}{dt}(PE_{SPRING})$

4. $F = -k\,[\,(x_2 - x_1) - l\,]$

UNKNOWNS

1. **F**
2. f_k
3. v
4. x_1
5. x_2
6. **t**
7. **N**

THE NUMBER OF RESULT VARIABLES EQUALS THE NUMBER OF EQUATIONS

Select a value for **t** or any other of the unknowns and solve the $\boxed{6}$ independent equations for the remaining unknowns (N.B. called 'result variables')

NOTES :

Eliminate the total energy equation due to its complexity !

CONSERVATION PRINCIPLES IN ENGINEERING, ECE 394A

DEMING'S FOURTEEN POINTS - REVISED FOR ECE 394

1) Create constancy of purpose toward improvement of knowledge, know-how, wisdom, and character through education with the aim to become competitive and to stay productive in society.

   Problem : Instructors are not ready to deal with wisdom and character.

2) Adopt the new Philosophy. We are in a new economic age. Instructors, students, and administrators must awaken to challenge, must learn their responsibilities, and take on leadership for change.

   Problem : Administration is unwilling to support major changes.

3) Cease dependence on grades to achieve quality. Eliminate the need for testing on a mass basis by building quality into the student in the first place.

   Problem: Criticism by society and future employers who believe that the future performance of any employee can be predicted based on test taking and grades obtained.

4) End the practice of educating and evaluating academic success on the basis of grades. Maximize instead the competency of the graduates. Streamline the faculty so that courses based on competency levels are taught by the same group of instructors.

5) Exceed employers' expectations of graduates' quality through continual improvement of the educational process; thus, continually maximizing graduates' competency.

6) Institute faculty development courses in such areas as communication and inter personal skills.

7) The aim of teachers should be to help students and themselves increase the quality of education. Teachers need to be retrained, and teachers and students need to cooperate in the learning environment.

8) NO FEAR !

   The student <u>and</u> teacher should abolish all grades, tests, etc. and should work together so everyone benefits and succeeds.

9) NO BOXES !

Integrate classes so student has one broad body of knowledge instead of many little ones that sh/he might not be able to connect. Different instructors must team together to avoid any barrier problems.

10) Quit complaining about student success rate, start change in educational process.

Problem : Inflexible institutions due to fear of change.

11) Eliminate grades, competition between students. Substitute cooperative learning.

12) Remove barriers that rob students and teachers of confidence in the educational process. This means concentration on the quality of education in the students rather than the quantity of the education (i.e., taking responsibility for one's self education).

13) Institute a vigorous program for the need of quality education which will ultimately improve self and community.

14) All teachers and students must work together to instill a more rapid and smooth modification of the current system to reinforce commitment and leadership.

Problem : Inflexible institutions due to fear.

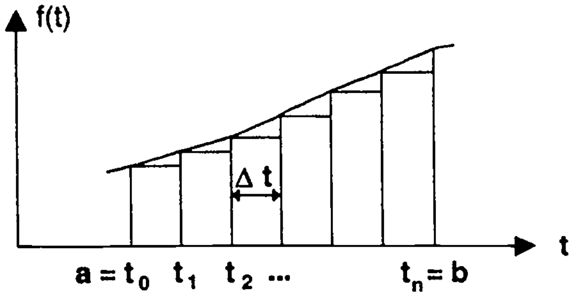
THE DEFINITE INTEGRAL

Distance travelled = Integral of velocity function

Definition:

The definite integral is a limit of Riemann sums.

$$\int_a^b f(t)\,dt = \lim_{n\to\infty}\left(\sum_{i=0}^{n-1} f(t_i)\Delta t\right)$$



Interpretation of the definite integral:

Distance travelled = Integral of the velocity function.

Total Change = Integral of the rate of change.

Area under graph = Integral of postiive function.

Average value of f(x) from a to b = $\dfrac{1}{b-a}\int_a^b f(x)\,dx$

The fundamental theorem of calculus

If f = F' then $\int_a^b f(t)\,dt = F(b) - F(a)$

STRUCTURE

Not all the following need to apply to each problem

DEFINE THE PROBLEM

- Draw a picture. Label everything that might be involved in the problem. List the given data in the picture.
- Identify all relevant variables.
- Which variables are a function of which variables?
- Write down formulas for the function where possible. (There is no need yet to simplify them at this time.)
- Sketch graphs of the functions. Completely label the graphs.
- Obtain numerical values / estimates; what are reasonable ranges for the variables.)

DECIDE ON A SOLUTION STRATEGY

- What is (are) the unknown(s)?
- Which mathematical structures are applicable?
- What are possible solution methods?
-

SOLVE THE PROBLEM

-
- Is the solution exact? If not, do you have error estimates?

PREPARE A REPORT

TASK[1]

Section 3.3, Exercise 11

If you jump out of an airplane and your parachute fails to open, your downward velocity *t* seconds after the jump is approximated by

$$v(t) = \frac{g}{k}(1 - e^{-kt})$$

where $g = 9.81\frac{m}{\sec^2}$

and $k = 0.2\sec^{-1}$

(a) Write an expression for the distance you fall in *T* seconds.

(b) If you jump from 5000 meters above ground, for approximately how many seconds do you fall before hitting the ground?

[1]Deborah Hughes-Hallet et al., *Calculus, Preliminary Edition*

Where Will Change Originate ?

The biggest and most long lasting reforms of undergraduate education will come when individual faculty or small groups of instructors adopt the view of themselves as reformers within their immediate sphere of influence, the classes they teach every day.

K. Patricia Cross

How Should Change Take Place... University of Alabama Tuscaloosa

1. Truly interested faculty --> GO!
2. Atmosphere conducive to trust.
3. Top Down and Bottom Up and Democratic process of decision making.
4. Listen to 'customer'; technology push; cooperation and support -- those affected participate.
5. 'Bottom UP' vision from top (inspiration).
6. Establish needs; decide on change; gather support; then institutionalize.
7. Bottom up and incentives must be present.