Integration of Statics and Particle Dynamics in a Hands-On Project-Oriented Environment

Christopher D. Pionke, J. Roger Parsons, J. Elaine Seat, Fred E. Weber, Daniel C. Yoder

The Engineering Fundamentals Division *engage* Program
The University of Tennessee

Abstract

Two new courses have been developed at the University of Tennessee (UT) as part of the Engineering Fundamentals Division *engage* program. Each course is 6 semester hours and they are entitled EF 101 - Engineering Approaches to Physical Phenomena and EF 102 - Fundamentals of Engineering Mechanics, respectively. The courses are taken in sequence during the freshman year by students in all engineering majors. An overview of the entire program and details of the EF 101 course (which emphasizes problem solving and various computer skills such as programming and graphics) have been presented previously. The focus of this paper is the EF 102 course. In particular, this paper will outline how statics and particle dynamics are presented in an integrated, collaborative learning environment that includes traditional presentation techniques, hands-on practice in an open-access laboratory, and application through the use of design projects that are developed through the build and test stages.

The philosophy of the new course can be summarized as: see the concept, feel the concept, practice the concept, and apply the concept. The "see the concept" phase is presented by a professor in a traditional lecture setting that includes all necessary background material and derivations. A simple example may also be presented. On the same day that a topic is introduced, all the students must go to a open-access laboratory and perform a "physical homework" to "feel the concept." In this open-access laboratory, students actually solve statics and dynamics problems by measuring forces, moments, velocities and accelerations, and comparing those results to calculated predictions. The assigning of traditional homework problems and attendance at recitation or problem sessions provide further "practice of the concept". Graduate teaching assistants run the recitation sessions. During the recitation sessions, the students work problems in small teams in a collaborative learning environment. Finally, team design projects are assigned to allow the students to "apply the concept." These projects usually require the integration of several concepts developed in the course as well as the use of computer tools developed in the EF 101.

This paper provides the details of the *engage* strategy for the EF 102 course including examples of the integrated material and teaching methods. Details of how a concept is presented and reinforced through the four phases (see, feel, practice, and apply) will be outlined. Examples of how computer skills developed in the EF 101 course are integrated with the mechanics concepts presented in the EF 102 course are also presented. Preliminary results from a pilot

program conducted in the 1997-1998 academic year are very promising and these results will also be presented. Discussion of the current transition program being conducted in the 1998-1999 academic year are also included. The current time-line requires that the integrated *engage* program will be fully implemented in the 1999-2000 academic year.

Background

In 1996, the University of Tennessee College of Engineering began to examine its Freshman Engineering program. Advice on the current state of the program and how it could be improved was sought from students, alumni, faculty, and industry. The resulting message was clear. According to those polled, the Freshman Program must do the following: 1) maintain the current technical content; 2) integrate the course material to enhance learning; 3) require teamwork and an introduction to design; 4) teach communications skills; and 5) emphasize problem-solving skills. The program at the time consisted of five separate courses and was not meeting the stated requirements. These courses consisted of a statics course (3 hrs), an engineering graphics course (3 hrs) and a seminar course (1 hr) taught in the first semester, and a dynamics course (3 hrs) and a computer programming course (3 hrs) taught in the second semester.

After more than year of work, a dedicated committee chosen by the dean completely reorganized the freshman program to ensure an integrated approach to the curriculum. The five existing courses were replaced by two new six-hour semester courses. The first course is entitled EF 101 - Engineering Approaches to Physical Phenomena. This course emphasizes problem-solving, teamwork, design, and computer tools (engineering graphics using AutoCAD's Mechanical Desktop and computer programming using MatLAB), all based on the study and use of low-level introductory physics.

The second course is entitled EF 102 - Fundamentals of Engineering Mechanics, and integrates an entire semester of statics and an entire semester of particle dynamics into one course. The EF 102 course assumes mastery of the techniques and tools from the EF 101 course, and forces students to make extensive use of those tools. The statics and dynamics are taught in an integrated manner with the use of lectures, problem solving sessions, a hands-on laboratory, and design projects.

Both EF 101 and EF 102 are taught by the newly created Engineering Fundamentals Division and both courses are taken by all freshman engineering students.. The entire new integrated curriculum is entitled the *engage* program. In the 1997-98 academic year, 60 students went through a "pilot" section of the new *engage* program. During the current academic year (1998-99), 150 students are enrolled in a "transition" section of the *engage* program. Full implementation (approximately 400-450 students) is planned for the 1999-2000 academic year.

Details of the *engage* program development process, the EF 101 course, and the hands-on laboratory have been reported earlier [1,2]. This paper focuses on the EF 102 course. Details of the course structure, how the material is integrated, and examples are all presented. Results from the 1997-98 pilot section of the program will also be presented.

Course Structure

In EF 102, there are nine contact hours per week and the course meets every day. The contact hours are divided into four basic components which are:

1) Lecture - three 50 minute sessions per week, M-W-F, usually in the morning
2) Hands-On Lab - one or two 50 minute sessions per week, M or W (or both) afternoons
3) Analysis and Skills (A&S) - one 50 minute session on Tu, two 50 minute sessions on Th
4) Team Project Time - one 50 minute session on Tu, one 50 minute session on F

One lecture, one hands-on lab, one analysis and skills session, and one team project time are called a "cycle." Therefore, there are two cycles per week with M-Tu comprising one cycle and W-Th-F comprising the other cycle. Four to six cycles (two to three weeks) comprise a "module." A module is a block of related material. Figure 1 outlines all modules for the course. There are three statics modules, four dynamics modules and one review module. Specific descriptions of the content and format of each of the four components follow.

<u>Lecture</u>

This is where the students "see the concept." All lectures are conducted by a professor in a large hall with up to 150 students per session. The format is fairly "traditional" with the professor presenting and outlining new technical material such as symbol definitions, equation derivations, etc. There is some interaction between the professor and students, but only limited active collaborative learning (ACL) techniques are utilized.

The goal of the lecture is to provide information on a new concept that will supplement and/or clarify information in the textbook. Students are expected to have read the covered sections prior to class. A short example may be presented, but completely worked out problems are usually not presented. The idea is to introduce and expand on a new concept and not necessarily illustrate all of it's applications. Homework is assigned in the lecture. Typically two homework problems are assigned to be turned in for credit at the next lecture. Also, two other "suggested homework problems" are usually assigned. These "suggested" problems are not graded, but provide additional practice on the covered concept. New material is usually only introduced in the M-W lectures (i.e., the start of each cycle). Fridays are usually reserved for review, quizzes and exams.

<u>Hands-On Lab</u>

This is where the students "feel the concept." The hands-on labs are conducted by graduate teaching assistants (GTAs) under the guidance of a professor. The purpose of each lab is to help the students develop a physical "feeling" for the concept most recently presented in the lecture. To accomplish this goal, each lab must do three things: 1) briefly restate and reinforce the background and the covered concept; 2) give students a physical experience with the new concept; and 3) require students to analyze the physical results in light of the covered concept. The idea is to force the student to use the concept to figure out how to approach the physical example, and then to apply the physical example to describe the concept.

Date	Text (Meriam & Kraige)	Topic
	MODULE 1: FORCES, MOMENTS, COUPLES	
1/14, 15	1.1 - 1.8, 2.1 – 2.3 (Statics)	Vectors, forces
1/16	2.4 – 2.5	Moments and couples; Cross products
1/19		MLK Holiday
1/21, 22	2.6	Resultants of force systems
1/23		QUIZ – Vectors, forces, and moments
	MODULE 2: EQUILIBRIUM	
1/26, 27	2.7 – 2.8	Rectangular components of forces in space / dot products
1/28, 29	2.8 – 2.9	Resultants of 3-D force systems
1/30	3.1 – 3.3	Equilibrium; FBD
2/2, 3	3.4 – 3.5	Resultants and equilibrium in 3-D
2/4, 5		Review and catch up
2/6		EXAM 1 – Modules 1 and 2
	MODULE 3: TRUSSES, FRAMES, MACHINES	
2/9, 10	4.1 – 4.3	Trusses – methods of joints and sections
2/11, 12	4.4 – 4.5	Trusses – method of sections; Space trusses
2/13	4.6 – 4.7	QUIZ – Trusses; Start frames and machines
2/16, 17	4.6 – 4.7	Frames and machines
2/18, 19	4.1 – 4.7	Frames and machines; Review of Module 3
2/20		EXAM 2 – Module 3
	MODULE 4: KINEMATICS OF PARTICLES	
2/23, 24	2.1 – 2.2 (Dynamics)	Newton's laws; Rectilinear motion
2/25, 26	2.3 – 2.4	Constant acceleration; Rectilinear and curvilinear motion
2/27	2.1 – 2.4	Review catch up then QUIZ on sections 2.1 – 2.4
3/2, 3	2.5	Normal and tangential coordinates
3/4, 5	2.5; 2.8	Normal and tangential; Translating axes
3/6		EXAM 3 – Modules 4
	MODULE 5: NEWTON'S SECOND LAW	
3/9, 10	3.1 – 3.5	Second law: Rectilinear and curvilinear motion
3/11, 12	3.1 – 3.5	Connected bodies
3/13	Review	Review and catch up
3/16, 17	6.1 – 6.3 (Statics)	Friction
3/18, 19	6.1 – 6.3 (Statics)	Impending slip, tip
3/20		QUIZ – 2^{nd} Law
	March 23 – 27, SPRING BREAK	
3/30, 31	3.1 – 3.5	Kinetic friction
4/1, 2		Review
4/3		EXAM 4 – Module 5
	MODULE 6: WORK & ENERGY	
4/6, 7	3.6	Work – Energy
4/8, 9	3.6	Work – Energy principle
4/10		
4/13, 14	3.6 – 3.7	Conservation of Mechanical Energy
4/15, 16		QUIZ – Work & Energy
	MODULE 7: LINEAR IMPULSE & LINEAR MOMENTUM	
4/17	3.8 – 3.9	Linear Impulse & Momentum
4/20, 21	3.8 – 3.9	Linear Impulse & Momentum
4/22, 23	3.11 – 3.12	Impact
4/24		Exam 5: Modules 6 & 7
	MODULE 8: COURSE REVIEW	
4/27, 28		Review of Statics
4/29, 30		Review of Dynamics
5/1		Review for Statics Final Exam
5/4		Review for Dynamics Final Exam

Figure 1. Course Outline, Spring 1998

This hands-on learning experience is presented as a "physical homework" assignment to emphasize that this is something the student must do, and not simply a demonstration that the professor thinks is "cool." Students work in pairs (to encourage peer teaching), and their work is evaluated by one of the GTAs staffing the lab. This evaluation is on a proficiency basis, which means that both students in the pair must demonstrate a grasp of the concept and an ability to use it. If either student fails to show proficiency, the pair is sent back for more experimentation and review until they can prove proficiency. Once they have done so, they receive full credit for the assignment. A very detailed description of the hands-on lab for both the EF 101 and EF 102 course have been presented previously [2].

Analysis & Skills

This is where the students "practice the concept." Analysis and skills sessions are conducted by GTAs under the guidance of the lecture professor. In the A&S session on Tuesdays and one of the A&S sessions on Thursdays, the students work at least two (sometimes as many four) practice problems. These practice problems are similar to the assigned and suggested homework problems. The goal is to provide the students with additional insight and aid them in completing the required homework. No new material is presented in this part of the A&S sessions.

Active collaborative learning (ACL) techniques are extensively used in these sessions. Occasionally the GTA will present a worked out example on the board, but most of the problems are actually worked by the students in groups of two or three under the guidance of the GTA. Students will often present their solutions on the board to the class. There are 25 to 30 students and 2 GTAs in each A&S session which enables a significant amount of peer-peer and peer-mentor contact.

The professor’s role is to review all the problems (assigned, suggested, and practice) with the GTAs and discuss the concepts and insights the students should come away with at the end of each A&S session. The entire EFD faculty provides guidance to the GTAs in developing their comfort and use in ACL techniques. Occasionally, all EFD faculty will "guest conduct" an A&S session.

The second 50 minute A&S session on Thursdays is reserved for further computer skills development. As stated previously, most of the required computer skills are presented and developed in the EF 101 course. However, a few "advanced" topics in graphics and computer programming are developed and presented in this course (such as assembly drawings and numerical integration). The presentation of this material is conducted by the GTAs under the guidance of a professor. The professor is responsible for the outline of the scope and coverage of the new material as well as developing all teaching materials (lecture materials, example problems, etc.). These sessions are usually conducted in the computer laboratory.

Team Project Time

This is where the students "apply the concept." These sessions are conducted by a professor with the assistance of GTAs and undergraduate "team facilitators." The GTAs and the undergraduate team facilitators serve two different roles. The GTAs help in technical guidance for the students. They supplement the technical assistance given by the professors. They also schedule and supervise non-class time openings of the project work room. The undergraduate facilitators assist the students in dealing with issues such as teamwork and conflict resolution. All facilitators are undergraduate engineering students who must enroll in a special class entitled Counselor Education and Counselor Psychology (CECP) 201 where they are trained in group dynamics, conflict resolution, etc. Previous papers have provided details on this course and how it integrates with the *engage* program [3].

The majority of the class time is utilized by the students to work on their current project. Occasionally new material on general design principles, scheduling, teamwork, etc. is presented. This material is presented by the professor. These projects usually cover several modules and usually there are only two or three projects per semester (one statics project and one or two dynamics projects).

Example Module

Details of one module will be presented. The chosen module is Number 6, Work and Energy. Refer to Figure 2 for the length, timing, and coverage of this module.

Lecture

The lecture sessions follow a "very traditional" format. In the first lecture of this module the basic definitions and nomenclature for work and kinetic energy are derived and introduced. Work done by normal, tangent, and spring forces are also presented. Homework and suggested problems requiring the calculation of the work done by a variety of forces are assigned.

In the second lecture of this module, the work-energy equation is derived and presented. The derivation and definition of power and efficiency are also presented. Homework and suggested problems requiring the use of the work-energy equation, and the power and efficiency equations are assigned.

The third lecture (a Friday) is reserved for review and additional examples. In the fourth lecture of this module, the definition of potential energy is presented. Potential energy of weight and spring forces are also presented. The derivation and definition of conservation of mechanical energy is also presented. Homework and suggested problems requiring the use of the conservation of energy are assigned.

The fifth lecture is a review. The sixth lecture is a "quiz" over work and energy only. In the program, a "quiz" is short exam over the most recent material. It is usually one question. An "exam" covers one or more modules and will have at least three questions. The exam at the end of module seven will cover material from both modules six and seven.

Hands-On Lab

There are two hands-on labs for this module. These labs occur at the beginning of cycle 2 and cycle 3 of this module. For each hands-on lab, students are provided with a one or two-page worksheet as shown in Figures 3-5. Each worksheet begins with a summary of the material presented in lecture, refreshing the development of the concept and serving as additional study notes. This background material develops all equations necessary for the assignment. The worksheet continues with a step-by-step guide to the experiment itself, describing what needs to be done and what data should be collected. This is followed by an Analysis section, which asks general questions about the behavior of the experiment and the results. These questions often require substantial thought, and their object is to force students to approach the concept from as many different angles as possible.

Lab 6.1 is concerned with work only. A copy of the lab handout sheet is provided in Figure 3. The scope of the lab involves the calculation of work of friction for various different items. There is a circular "chute" about 4 feet long and angled at 45 degrees in which various common items like erasers, nuts, and felt markers are inserted. After the items exit the chute the students measure stopping time and distances. From the estimated exit velocity (using kinematics and the data collected) and the distance traveled, the students calculate the amount of work performed. Students are required to think about the accuracy of their measurements, estimates, and calculations. They are also required to think about the physical differences and similarities between the various items and discuss how these effect their dynamic behavior.

Lab 6.2 expands on work and energy by including potential energy of gravity and springs. The worksheets for Lab 6.2 are shown in Figures 4 and 5. The first part of the lab details the experiments and calculation of the work done by a spring and the calculation of a spring constant. Bungee cord is used and the concept that all springs are "linear" is challenged by the experiment. Task two involves the calculation of the work of friction again. Task three involves the experimental validation of the conservation of energy.

Analysis and Skills

The majority of this time is spent working problems similar to those assigned in the lectures outlined above. The computer part of the Analysis & Skills sessions (1 hour on Thursdays) is spent on using MatLAB to perform polynomial curve fitting and numerical integration. The students will use these techniques to calculate the work done by a non-linear spring as part of their design project outlined in the next section.

Team Project Time

The Spring 1998 dynamics project was a variation of a project originally developed at Arizona State University. The project was entitled "The Bungee Omelette - NOT" project. The basic idea was that each team had to design a bungee cord that would safely drop an ordinary sandwich bag containing up to four raw eggs a specified distance and just barely "touch down" in a sand pit. The eggs could not be damaged.

Lab. Worksheet 6.1 - Work and Energy
EF 102 – Fundamentals of Engineering Mechanics

Objectives:
- to develop a better basic understanding for the concepts of energy and work
- to better appreciate how useful that tool is in solving dynamics problems

Background
- text section 3.6, lecture 4/6 **-** 4/9

Summary:

Work is defined most simply as a force exerted over some distance or displacement (the distance over which the object of interest moves). Back last semester when things were easy we worked with forces acting in the direction things were moving, which gave us the simple equation U = F * Δs (I'm not sure why they chose U to represent work rather than W; probably just to confuse us more). The more general form is that a tiny little piece of work dU = **F** • d**s**, which is the dot product between two vectors. **F** is the force vector, and d**s** is the vector path over which the object moves. Figure 3/2 on p. 157 shows this well, except that they confuse things by using d**r** for the path when they use **r** for the position vector. I prefer to use **s**. Then, just like we add up all the little dy or dx in integrating, we can add up all the little dU to get U, which is the total work done.

Remember that **F** • d**s** = F * ds * cos(α), where ds is the magnitude of d**s** and α is the angle between **F** and d**s**. You can thus think of the work in one of two ways: 1) the force times the displacement component along the line of action of the force, or 2) the displacement times the force component along the line of action of the displacement. The force component perpendicular to the displacement does no work, since cos(90) = 0.

The total description for work is therefore U = ∫ **F** • d**s**, which can be broken down into components as U = ∫ (F_x dx + F_y dy + F_z dz). Another way to look at it is to break **F** down into the component along the path (F_t) and perpendicular to the path (F_n), and to realize that F_n contributes nothing to the work. Then U = ∫ F_t ds.

Procedure
<u>*Task 1.*</u>
Your object is the marker, for which you know the mass.
a) using kinetic energy principles, calculate the work done by friction from the time the marker leaves the chute until it comes to a stop in the channel.
b) now calculate the work done by friction based on kinetic friction principles.
c) compare your results

<u>*Task 2.*</u>
Estimate what the stopping distances in the channel would be for one of the large nuts and for an eraser. Take whatever measurements are necessary, but do not actually measure the stopping distance.

Analysis
<u>*Task 1.*</u>
How did the two values of work compare?
In which would you have more confidence, and why?
<u>*Task 2.*</u>
Explain how you did this task.
The marker, nut, and eraser do not come out of the chute with the same velocity. Why not? Could you use this fact to estimate the kinetic friction of the objects in the chute? Show how you would do this.

Figure 2. First Hands-On Laboratory Example

Lab. Worksheet 6.2 - Work and Potential Energy
EF 102 – Fundamentals of Engineering Mechanics

Objectives:
- to expand the concepts of work and energy to include potential energy
- to provide additional practice in using work-energy relationships

Background
- text section 3.7. lecture 4/13 - 4/15

Summary:

Recall that work is defined as a force exerted over some distance or displacement, with the general form being that a tiny little piece of work dU = **F** • d**s** = F * ds * cos(α), where ds is the magnitude of d**s** and α is the angle between **F** and d**s**. Work can be seen in one of two ways: 1) the force times the displacement component along the line of action of the force, or 2) the displacement times the force component along the line of action of the displacement. The force component perpendicular to the displacement does no work, since cos(90) = 0. The total description for work is U = ∫ **F** • d**s**, which can be broken down into components as U = ∫ (F_x dx + F_y dy + F_z dz). Another way to look at it is to break **F** down into the component along the path (F_t) and perpendicular to the path (F_n), and to realize that F_n contributes nothing to the work. Then U = ∫ F_t ds.

Potential energy is work that is stored, and that may later be converted back into doing work. The most common storage is performed by lifting an object into the air. If we have a rope hooked to the object over a pulley we can then clearly get work back out as the object falls back to the ground. We might think of it as storing energy in the gravity field between the object and the earth. This gravitational potential energy is equal to the work done lifting the object in the first place, and is defined as V_g = m g h where m is the object's mass, g is the acceleration due to gravity, and h is the distance above some assumed zero level. This level is sometimes assumed to be the center of the earth, sometimes is sea level, sometimes the ground surface, or some other level. We can change this around at will be cause the work done by going from a low level h_1 to a higher level h_2 is the change in energy, or $U_{1-2} = \Delta V_g = m\ g\ \Delta h = m\ g\ (h_2 - h_1)$.

We can also store potential energy by stretching or compressing molecular bonds, like in a spring or in a bent board. This is most commonly called elastic potential energy. In this case the force required to change the spring length or to bend the board further depends on how far it has already been pushed. The most common assumption is that this relationship between force and deformation is linear, or F = k x, where x is the distance the spring has been compressed from its at-rest undeformed position (I sometimes find it less confusing to think of it as ΔL rather than x), and k is the spring constant. Other assumptions are sometimes made for other types of materials. Based on the linear assumption, the work done to deform a spring is equal to the energy stored in it, or

$V_e = \int kx\ dx = ½\ k\ x2$

As the spring is increasingly deformed from x_1 to x_2, the change in elastic potential energy (the elastic work) is

$U_{1-2} = ½\ k\ (x_2^2 - x_1^2)$.

We can finally combine these forms of energy into one work-energy relationship, which is that

$U_{1-2} = \Delta T + \Delta V_g + \Delta V_e$,

where
$\Delta T = T_2 - T_1 = ½\ m\ (v_2^2 - v_1^2)$,
$\Delta V_g = m\ g\ (h_2 - h_1)$,
$\Delta V_e = ½\ k\ (x_2^2 - x_1^2)$.

Figure 3. Second Hands-On Laboratory Example, Part 1

Lab. Worksheet 6.2 - Work and Potential Energy
EF 102 – Fundamentals of Engineering Mechanics

Procedure (these are taken from a lab at the end of last semester, but hopefully can be done this semester with greater understanding)

Task 1.

1) Take the bungee cord with the attached weight holder. Measure the height of the bottom of the holder above the floor. Now add 100g of weights to the holder, and measure the distance that the holder drops. What is happening here is that we are taking the ΔV_g of the weights and converting it into ΔV_e in the bungee cord. What we want to do is use the definitions of ΔV_g and ΔV_e to determine the spring constant k of the bungee cord, assuming a linear spring constant.
2) Now add another 100g of weights to the holder, and use the full stretch over the 200g to once again calculate the value of k.

Task 2.

1) Using the small ramp, roll a tennis ball over the course and measure the time required for the ball to move between the 20-ft and 25-ft markings.
2) Using this time and distance (5 ft), calculate the average velocity of the ball in this section.
3) Calculate the kinetic energy T for the ball as it rolls through this section.
4) Calculate the V_g for the ball before it is dropped.
5) Calculate the change in energy, which will be the work done on the ball by friction.
6) Knowing that work is force times distance, calculate the average friction force on ball from the time it is dropped in the ramp.

Task 3.

1) Drop a tennis ball from waist height, and measure the height to which the ball bounces back up.
2) Calculate the energy level of the ball before it is dropped, and when it is at the top of its first bounce.
3) Calculate the percentage energy loss in the bounce.
4) Calculate the velocity of the ball just before it hits the ground.
5) Calculate the velocity of the ball just after it leaves the ground, assuming that the total energy loss occurs in the bounce itself (the loss of energy to air friction is assumed to be negligible).

Analysis

Task 1.

- How would the calculations be different it you assumed a quadratic form ($F = k x^2$) for the spring constant relationship?
- Did you get the same k going from 0-100g as from 100-200g? What does this tell you about your linear assumption for k?

Task 2.

- This analysis assumes that the friction loss occurs evenly over the entire distance. Is this reasonable? Where would you guess that most of it does occur? How could you test this?
- Draw two FBD's of the ball; one assuming that there is no friction, and one assuming that there is friction. Explain what difference the assumption of friction or no friction makes on the energy analysis.

Task 3.

- You calculated an energy loss; where did that energy go?
- Is the energy loss in the bounce taken into account in our standard work-energy relationship?

Figure 4. Second Hands-On Laboratory Example, Part 2

The students were given the drop distance and the number of eggs on the morning of the test. The students had to resolve at least two problems related to their "real" system. The first was the variability in mass of each individual egg. The second was the non-linearity of the bungee cord. Most teams resolved the first problem by creating ballast weights to be added at the time of the drop. The mass of the eggs was determined just prior to testing and enough ballast weights were added to bring the total mass up to a pre-determined value. This pre-determined value was used in their experimental procedures.

Most teams resolved the second problem by writing a MatLAB program of the work-energy equation that included the non-linear bungee cord. The non-linear characteristics of the bungee cord was determined experimentally by the students. The students used various polynomial curve fits of the data until they were confident in the level of precision of the model. The actual drop mass and distance were then entered in the program. The MatLAB program then output the length and number of cords required to safely drop the sandwich bag containing the eggs.

Results and Discussion

In order to assess the new integrated approach to teaching mechanics, two "common final exams" were administered in the spring of 1998. These exams consisted of "traditional" statics and dynamics problems with the exception that at the end of each question, the students were given a choice of at least ten multiple choice answers. The students were told to work out the problems as they would in a "normal" exam, and then choose the answer that most closely matched their solution. For the statics exam, many of the alternative choices corresponded to common types of mistakes such as sign errors.

Both of the final exams were given to all of the students enrolled in the integrated *engage* program. Students enrolled in the "traditional" program took the exam that corresponded to the course in which they were currently enrolled. There were approximately 120 students in the "traditional" statics course and 240 students in the "traditional" dynamics course. A summary of the exam results is given in Table 1.

As shown in Table 1, there was an improvement in the results for the students in the integrated *engage* program. For both the statics and dynamics exams, the *engage* students chose the correct answer about 45% of the time while the students in the traditional program chose the correct answer only about 37% of the time (percentage correct in the table). If the correct answer plus the answers to very common mistakes (percent correct + in the table) are considered, the trend is similar. For the statics exam 71% of the integrated *engage* program students chose the correct or nearly correct answer while only 57% of the students in the traditional program chose the correct or nearly correct answer (data is not available for the dynamics exam). The graded score is the average grade assigned by the instructors and includes all partial credit. Again the students in the integrated *engage* program scored higher than the traditional students on both exams.

Table 1. Summary of Common Statics and Dynamics Final Exam Results

Statics

	EFD Pilot Section	Traditional Program
Percent Correct	44	37
Percent Correct +	71	57
Graded Score	68	65

Dynamics

	EFD Pilot Section	Traditional Program
Percent Correct	45	36
Percent Correct +		
Graded Score	70	67

As noted above, the *engage* pilot group consisted of 60 incoming freshmen (no transfer students) who volunteered for the program during the summer of 1997. The students were chosen to match the distribution of ACT score, high school GPA, minority representation, and male/female ratio of the 1996-97 freshmen class. Of the 60 students who started the program, 42 finished the both courses with a passing grade.

A concern is whether or not the 42 students who finished the *engage* program is a large enough sample to develop statistically meaningful results. Also, at this point no comparison of the exiting demographics (i.e., those that completed both the *engage* and the "traditional" programs) have been made. Both of these questions are currently being investigated. This year (1998-99) there are 150 students who volunteered for the *engage* program and about 300 students in the "traditional" program. The same demographics mentioned above were matched between the two groups. The two sample sizes are large enough that statistical meaningful comparisons will be made between the groups. Results of these comparisons should be available in the fall of 1999.

Despite the lack of hard statistics at this point, the results from the 1997-98 academic year are very encouraging. The new integrated approach to teaching statics and dynamics as outlined in the engage program works and works well. The initial comparison data presented here indicates that students develop a better understanding of mechanics through this approach. In addition, they are also learning other valuable skills such as teamwork and technical communications. Similar results are anticipated for the 1998-99 academic year as well as when the program is fully implemented in the fall of 1999.

Bibliography

1) Gilliam, F., Klukken, G., Parsons, R., Pionke, C, Scott, T., Seat, E., Symonds, F., Weber, F., and Yoder, D., "Renovating the First Year Engineering Program at the University of Tennessee," *Proceedings of the Frontiers in Education Conference* , Phoenix, AZ, November, 1998, pp. 814-819.

2) Yoder, D.C., Parsons, J.R., Pionke, C.D., Weber, F., "Hands-On Teaching of Engineering Fundamentals," *Proceedings of the ASEE Annual Meeting* , Seattle, WA, June, 1998.

3) Knight, D., Poppen, W., Klukken, G., Parsons, J.R., Seat, J.E., "Training Upperclassmen to Facilitate Freshman Design Teams," *Proceedings of the ASEE Annual Meeting* , Seattle, WA, June, 1998.

Biographical Sketches

CHRISTOPHER D. PIONKE
Chris is an Assistant Professor in the Mechanical and Aerospace Engineering and Engineering Science Dept. at the University of Tennessee (UT). He received bachelor's degrees in Engineering Physics and Engineering Science and an MS in Engineering Science from UT. He received his Ph.D. in Engineering Science and Mechanics from Georgia Tech. He conducts research and teaches courses in mechanics and design. Email: cpionke@utk.edu

J. ROGER PARSONS
Roger is a Professor of Mechanical Engineering at the University of Tennessee (UT). He received his degrees from the University of Illinois, Carnegie -Mellon University and North Carolina State University, all in Mechanical Engineering. At UT since 1979, he teaches and conducts research in energy systems and innovation in the design process. Email: jparsons@utk.edu

ELAINE SEAT
Elaine is a NSF Visiting Professor working to establish the team facilitation courses to teach teaming and performance skills to engineering students. She received BS and MS degrees in Mechanical Engineering and the Ph.D. in Education specializing in Human Motor Behavior/Performance Psychology from the University of Tennessee. Email: seat@utk.edu

FRED WEBER
Fred is an Associate Professor in the Chemical Engineering Department at the University of Tennessee. He received his BS from the University of Michigan and his Ph.D. from the University of Minnesota, both in Chemical engineering. Email: fweber@utk.edu.

DANIEL C. YODER
Daniel is an Associate Professor in the Agricultural and Biosystems Engineering Department at the University of Tennessee (UT). He received all his degrees from Purdue University, all in Agricultural Engineering. At UT since 1991, he conducts research and teaches courses in soil and water conservation and hydrologic instrumentation. Email: dyoder@utk.edu