On the Use of Equation Solvers, Interactive Software, and Hands-on Projects in Integrated Sophomore Engineering Courses

Mario A. Medina
Civil, Environmental, and Architectural Engineering Department
The University of Kansas

Abstract

The long-term objective of this effort was to fundamentally change the quality of engineering instruction and student interactions-through the use of newest education technologies in the classroom. Three principal areas of student impact were identified. These were: (1) Improvement of the quality of engineering students, (2) Development of student social skills, and (3) Enhancement of student motivation to continue the learning experience. This paper recounts how equation solvers, interactive software, and hands-on projects were incorporated into sophomore level integrated courses and documents the observations, lessons learned, and conclusions from the experience. Student participants improved in understanding and applying fundamental principles, developed the ability to identify and define problems, knew how to evaluate alternative solutions, were better trained to communicate ideas, both orally and written, and were able to use technology for setting, solving, and presenting problems. In addition, the students enhanced their social skills by working in teams and by enhanced student/faculty interactions.

Introduction

In 1994, the College of Engineering at Texas A&M University-Kingsville (TAMUK) joined six other engineering programs from Arizona State University, Texas A&M University, University of Alabama, Rose-Hulman Institute of Technology, Texas Women's University, and Maricopa Community College to form the National Science sponsored Foundation Coalition (FC). The coalition was one of eight NSF-supported engineering coalitions, which were the ECSEL, Synthesis, Gateway, SUCCEED, Greenfield, Academy, SCCEME, and the Foundation [1]. The main thrust of the FC was to implement curriculum reform in engineering education. The reforms were to be explored and implemented in four major areas, which were curriculum integration, technology enabled learning, human interface development, and assessment, evaluation, and dissemination.

To date, FC partner campuses have reorganized their curricula, modernized or built new classrooms, and created faculty development projects guided by the four major areas listed above and by utilizing student teams in engineering and by increasing the participation of women and underrepresented minorities in engineering. Most projects have focused on the foundational years of the engineering curricula. The FC has created means to assist campuses that are involved in improving their learning environments and curricula [2].

TAMUK is located in Kingsville, Texas. It is the only comprehensive university and the only predominantly residential university in South Texas. TAMUK is committed to its role in the South Texas area through teaching, research, and service. Its mission of teaching, scholarly activity and professional service is considered essential to the advancement of knowledge and regional development. The university is a member of the HBCU-MI (Historically Black Colleges and Universities-Minority Institutions). Sixty five percent of its student body is of Hispanic background.

Curriculum Integration

Curriculum integration is viewed as a way to de-emphasize engineering discipline boundaries, which normally prevent students from "seeing" beyond a particular set of courses. For example, in typical engineering programs students learn about conservation laws early on. However, the fact that conservation principles are applied in the same manner whether one deals with mass, energy, charge, or angular momentum is not intuitively made. Curriculum integration is intended to develop this intuition in the student near the beginning of their academic training. As a result, the FC explored and planned the implementation of curriculum integration in the freshman year and the sophomore year. The universities were left to propose, design, and put into practice the integration of their first year curricula and second year curricula as they saw it applicable. 'Integration' ranged from organizing courses with interdependent topics back-to-back [3] to team-taught courses by physics, math, and engineering faculty [4] to creating 12-credit-hour courses, which included an array of common topics from amongst the disciplines [5]. Of the lessons learned, one that stood out was the fact that there is no ideal way or structure for curriculum integration.

At TAMUK, the first year of the curriculum was integrated through scheduling those traditional courses most engineering students take during each semester back-to-back in two to three hour blocks. The course alignment (shown in Table 1.) was followed by a review and revision, made by the participating faculty, of courses contents based on fundamental areas that are crucial for the students to master by the end of the first year. These areas were basic skills, thematic concepts, and problems solving strategies and design. Participating faculty members met regularly on a weekly basis to map and to assemble course topics and to plan the delivery strategies. Weekly integrated syllabi were prepared, which were revised regularly and changed when necessary. In addition, instructors normally visited each other's classes. Needless to say, the faculty interactions were indeed very rewarding for those who participated.

Table 1. Integrated First Year Courses [3]

Fall Semester		**Spring Semester**	
Courses	**Credits**	**Courses**	**Credits**
Chemistry I w/ Lab	4	Chemistry II w/ Lab	4
Analytical Geometry	3	Calculus I	3
Comp-based Graphics Design I w/Lab	3	Comp-based Graphics Design II w/Lab	3
English I	3	Physics I w/ Lab	4
University Success	2	English II	3
TOTAL	15	TOTAL	17

Integrated and interdisciplinary design projects were incorporated into the effort. This endeavor was in line with ABET 2000 design requirements. The first year experience was enhanced by the integration of English courses with the science and technical courses. A standard format for developing and presenting technical reports was developed and introduced to the students with great success. Furthermore, the students wrote technical research papers during their freshman year. Integrated exams were also given to the students [6].

The second year integrated curriculum was developed based on the lessons learned from the First-Year efforts and from other FC resources. With the idea of building upon the first year developments, a team of faculty from engineering, physics, and mathematics, who normally taught sophomore level courses, operated using weekly workshop sessions where the principles of teaming were applied following an established code of cooperation. Starting with a list of approximately 70 potential topics that are normally covered in standard sophomore curricula, an Affinity Process was used to group the topics. A Modified Nominal Group Technique was then used to prioritize the topics within the groups. Eight major groups of topics emerged. These were organized as follows [4]:

- System Analysis
- Energy Dynamics I
- Electricity and Magnetism
- Advanced System Analysis
- Conservation Principles
- Energy Dynamics II
- Mechanics I
- Mechanics II

From here, it was clear that there were two major categories: systems and mechanics. After agreeing on the arrangement of the topics as a function of delivery time, it was decided to develop the following four courses: Integrated Engineering Systems I and II and Integrated Mechanics I and II. These four courses were complemented and integrated with three other courses, which were Integrated Physics II and Integrated Mathematics III and IV. The Integrated Engineering Systems courses were 3-credit courses distributed in 2-credit lectures and 1-credit labs each. Integrated Physics II was a 4-credit course and the Integrated Mathematics courses were 3-credit courses each.

The course contents were further subdivided into major concepts where possible or just by topics. Integrated Engineering Systems I was subdivided into Systems Analysis, Energy Dynamics, and Electricity and Magnetism. Integrated Engineering Systems II was subdivided into Advanced Systems Analysis, Conservation Systems, and Advanced Energy Dynamics. Further details of the courses are provided in Table 2 and in [4].

Table 2. Integrated Engineering Sophomore Year Curriculum [4]

Course	Thematic Concepts	Topics
Integrated Engineering Systems I	Systems Analysis	** Identifying the System * Defining Variables * Identifying Constraints * Determining System Extent * Defining Initial and Boundary Conditions * Standard System Response Measures * Modifying System Behavior*
	Energy Dynamics	** Properties of a Substance * Heat * Work * Entropy * Heat Engines * Heat Pumps * Electromechanical Machines * Efficiency * Reversibility * Thermal Properties of Materials * Constant and Variable Density Fluids*
	Electricity and Magnetism	** Capacitance * Resistive Circuits * Impedance * Inductance * Steady State Kirchoff's Current Law * Semi-conductor Devices * Impedance Relationships * Magnetic Fields * Induction * Sensors * Transient State*
Integrated Engineering Systems II	Advanced Systems Analysis	** Specifying Objectives * Defining Time Period of Analysis * Multiple Energy Storage * Multiple Domain Systems * Identifying the State * Linear vs. Non-Linear Systems * Linearization * Analytical Methods*
	Conservation Systems	** Closed and Open Systems * Conservation of Mass * Rate Equation * Conservation Laws * Conservation of Linear Momentum * Conservation of Angular Momentum * Conservation of Net Charge * Rigid Body Angular Momentum * Accounting of Positive and Negative Charge * Conservation of Energy*
	Advanced Energy Dynamics	** Energy Possessed by Charge * Entropy Accounting * Energy in Transition * Energy Possessed by Mass * Other Topics Related to Entropy and the Second Law*
Integrated Mechanics I		** Forces * Moments * Free Bodies * Plane Areas (Reactions, Trusses, and Frames) * Plane Areas (Centroids, Moments of Inertia, and Products of Inertia) * Stress * Strain * Elastic Behavior * Thermal Expansion * Torsion and Torsional Stress * Beam Theory * Shear Diagrams and Stresses * Moment Diagram and Stresses * Deflections * Rotations*
Integrated Mechanics II		** Masses and Volumes * Particle Kinematics and Kinetics * Rigid Body Kinematics and Kinetics * Combined Stresses * Columns * Rotations*
Integrated Physics II		** Nature of Light * Geometric Optics * Relativity * Oscillatory Motion * Wave Motion * Sound Waves * Standing Waves * Superposition * Electric Fields * Gauss Law * Electric Potential * Magnetic Fields * Sources of Magnetic Fields * Faraday's Law * Electromagnetic Waves * Interference of Light Waves * Diffraction * Polarization * Quantum Physics*
Integrated Mathematics III		** Review of Vectors * Review of Several Variables * Partial Derivatives * Vector Fields * Line Integrals * Paths * Potential Functions * Multiple Integrals * Green's Theorem * Operations of Vector Fields * Fubini's Theorem * Surface Integrals * Triple Integrals * Coordinate Systems * Partial Differential Equations*
Integrated Mathematics IV		** Multiple Integration * Taylor's Theorem * Linearization and Stability Analysis * Hamilton's Approach with Mathematica * Modeling with Mathematica * Finite Differences * Mathematica Applications*

The FC Second Year curriculum was first offered in the fall of 1996. The courses were aligned and offered as follows:

Table 3. Fall 1996 Integrated Schedule

Time	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 – 9:30	*Integrated Math III*		*Integrated Math III*		*Integrated Math III*
9:30 – 10:00					
10:00 – 10:30	*Integrated Phys II*		*Integrated Phys II*		*Integrated Phys II*
10:30 – 11:00					
11:00 – 11:30		*Integrated Mech I*		*Integrated Mech I*	
11:30 – 12:00					
12:00 – 12:30					
12:30 – 1:00					
1:00 – 1:30		*Integrated Syst I*		*Integrated Syst I*	
1:30 – 2:00					
2:00 – 2:30					
2:30 – 3:00					

Table 4. Spring 1997 Integrated Schedule

Time	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 – 9:30					
9:30 – 10:00					
10:00 – 10:30	*Integrated Math IV*		*Integrated Math IV*		*Integrated Math IV*
10:30 – 11:00					
11:00 – 11:30	*Integrated Mech II*	*Integrated Syst II*	*Integrated Mech II*	*Integrated Syst II*	*Integrated Mech II*
11:30 – 12:00					
12:00 – 12:30					
12:30 – 1:00					
1:00 – 1:30					
1:30 – 2:00					
2:00 – 2:30					
2:30 – 3:00					

Participating faculty conducted weekly workshops to plan topic delivery, to organize lectures, projects, and exams as well as to organize the implementation of technology in these courses. The author of this paper taught the Integrated Systems I and II and Integrated Mechanics II; therefore, the use of computer tools and hands-on projects described in the following sections came from the participation of the author in the above-mentioned courses.

Technology Enabled Learning

The integrated curricula were taught in modified high tech classrooms. The students remained in the same classroom for all of their integrated courses. The first year curriculum was taught in a classroom located in the Physics building. The classroom was designed for a maximum of 24 students. It was equipped with 12 multimedia microcomputers with Internet access located along the periphery of the room. Software used to engage the students in the use of academic technology and projects included MAPLE, MATHEMATICA, Microsoft Office, CADKEY, a C compiler, ENCARTA, and TELNET. An extra microcomputer was for the instructors' use. This computer had all multimedia ancillary equipment needed to present electronic lectures. The core of the classroom consisted of rectangular tables, which allowed easy access for student

interaction. The second year courses were delivered in a similar room; this one located in the Engineering building. This room consisted of 16 microcomputers with Internet access and one for the instructor adapted with appropriate presentation technology. The software packages installed on these computers were the same as those of the first year program, but it added simulation software, such as interactive software for Integrated Mechanics I and II and Working Model, and equation solvers, such as Engineering Equation Solver (EES).

Tools Used

One of the main goals of the entire effort was to allow the participating students to construct their own knowledge with the help of the instructors, as opposed to a traditional curriculum where students are viewed as vessels waiting to be filled with knowledge and information. To this end the use of simulation technology and equation solvers was introduced in the courses. EES was predominantly used in the systems courses and interactive software was used in the integrated mechanics courses.

EES is an equation solver with built-in functions for thermal analyses with data of thermophysical and transport properties of substances (i.e., steam, air, ammonia, common CFC refrigerants, and commonly used gases). Added capabilities of the software of interest in the FC efforts included its ability to draw the system under analysis, the display of equations used, a solutions windows, a parametric table, and plots. In addition, integrated subroutines, which were used to solve differential and integral equations, to produce linear and non-linear regression, and to optimize proved to be significant help and resource in the overall effort [7].

The interactive software for Integrated Mechanics I and II provided a complete discussion environment relating to the study of mechanical systems simulation. It allowed the students to quickly reference and observe simple simulations of moving particles. During the simulation process the software showed vectors depicting forces, position, velocities, and acceleration with full reference to the equations under study [8].

In addition to the tools described above, for the hands-on projects the students used hand-held thermometers (glass filled, thermocouple, thermistors, etc.), multimeters (i.e., volts, DC current), weight balances, and length and volume readers.

Sample Activities

An important factor in the integrated activities was that students always worked in teams and observed collaborative learning codes of conduct. Collaborative learning is the educational method of teaching and learning that involves groups of students working together to solve a problem or complete a task. In the collaborative learning environment, students are challenged as they listen to different points of view, and are required to convey and defend their ideas. In so doing, the students create their own unique conceptual frameworks and don't rely solely on an instructor's or a text's framework. In a collaborative learning environment, students have the opportunity to actively interact with peers and instructors by presenting ideas, exchanging varied viewpoints, and question others. A second important factor was to keep the use of technology as simple as possible. The idea was to use the mentioned tools to learn, rather than to devote much

time to learning how to use the tools. The focus was on learning, not the technology, and to create a comfort level with the technology, not an infatuation with it.

The projects ranged from problem set ups, equation solutions, and simulations using computers to small experiment set up, data collection, interpretation of results, and report writing.

Sample Activity Using EES

The activities in which EES was used included problems in the areas of heat, work, entropy, heat engines, heat pumps, closed and open systems, conservation of mass, and conservation of energy. The problems were assigned so that the students could take advantage of the built-in fluid property routines and other capabilities of the software, such as parameterization. Despite the capabilities of the software, the student still needed to know the mechanics of solving the problems. This was needed to set up and to program the equations to be solved. The following sample activity is from *Integrated Systems II* (Spring 1998) [9]. The sample problem is from [10], which was one of the reference textbooks used for this course.

Problem Statement

Steam expands in a turbine steadily at a rate of 25,000 kg/h, entering at 8 MPa and 450 ^{o}C and leaving at 50 kPa as saturated vapor. If the power generated by the turbine is 4 MW, determine the rate of entropy generation for this process. Assume the surrounding medium is at 25 ^{o}C.

Solution

This problem involves the setting up of the energy and entropy balance equations for a steady state steady flow with a single stream system:

$$\dot{Q} + \dot{m}(h_i - h_e) = \dot{W}$$

where

$\dot{Q}$ = Rate of heat transfer between the control volume and its surroundings, kW

$\dot{W}$ = Power, kW

$\dot{m}$ = Mass flow rate, kg/s

h = Specific enthalpy ($u + Pv$), kJ/kg

where u = Specific internal energy, kJ/kg

P = Pressure, kPa

v = Specific Volume, m^3/kg

and

$$\dot{S}_{gen} = \dot{m}(s_e - s_i) - \sum \frac{\dot{Q}_k}{T_k}$$

where

$\dot{S}_{gen}$ = Total entropy generation rate, kW/K

s = Specific entropy, kJ/(kg K)

$\dot{Q}_k$ = Heat transfer rate through the boundary k at absolute temperature T_k, kW

T_k = Absolute temperature of surrounding medium adjacent to boundary k, K

Example of an actual program, written by one student [9], is given below.

```
"Entering Pressure"
Pi = 8000 "kPa"
"Entering Temperature"
Ti = 450 "C"
"Surrounding Temperature"
Tsurr = 25 "C"
"Exiting Pressure"
Pe = 50 "kPa"
"Power Generated by the Turbine"
W = 4000 "kW"
"Determine the mass flow rate by dividing by 3600 to get kg/s"
m = 25000/3600 "kg/s"
"Determine the entropy and enthalpy of the entering steam from Ti and Pi"
si = ENTROPY(steam, T=Ti, P=Pi)
hi = ENTHALPY(steam, T=Ti, P=Pi)
"Determine the entropy and enthalpy of the exiting vapor from Pe, and x=1"
se = ENTROPY(steam, x=1, P=Pe)
he = ENTHALPY(steam, x=1, P=Pe)
 "Determine the rate of heat transfer to the environment"
Q = W + m*(he-hi)
"Determine the rate of entropy generated by this process"
Sgen = (-Q/(Tsurr+273))+m*(se-si)
```

The program output was [9]:

```
Unit Settings: [C]/[kPa]/[kg[/[degrees]

hi   = 3272 [kJ/kg]      he = 2645 [kJ/kg]      m = 6.944
pi   = 8000              Pe = 50                Q = -353.9
si   = 6.555 [kJ/kg-K]   se = 7.593 [kJ/kg-K]   Sgen = 8.395
Ti   = 450               Tsurr = 25             W = 4000
```

The option of constructing property diagram proved very valuable. In the property diagram, Figure 1, the inlet and outlet states could be easily located, and by doing this the variables from the program output would tend to make more sense to the student than they would if this tool were not available. One of the most useful capabilities of the software was the development of parametric tables and graphs. At this point the student had the opportunity to readily answer many of the "what if" questions. For example, in the sample exercise, the students would ask, "what if the surrounding temperature were so and so?" A parametric table would be created, say from $T_{surr} = 0^oC$ to $T_{surr} = 40^oC$. The student would see that the rate of entropy generated by the process would decrease if the surrounding temperature increased. This is shown in Figure 2.

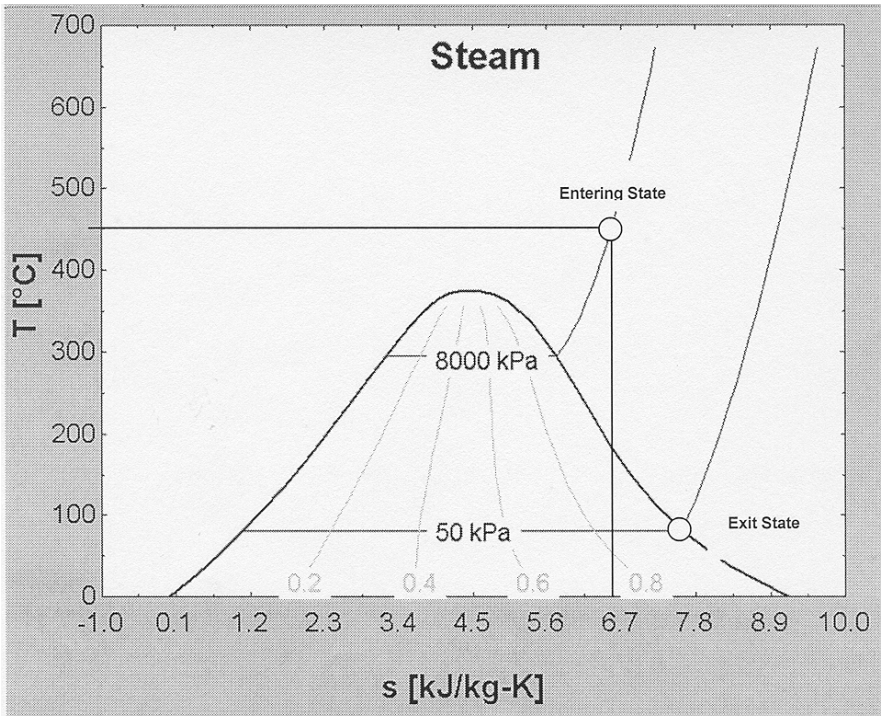


Figure. 1. Property Diagram Depicting Entering and Exit States in the Previous Sample Problem as Produced by EES

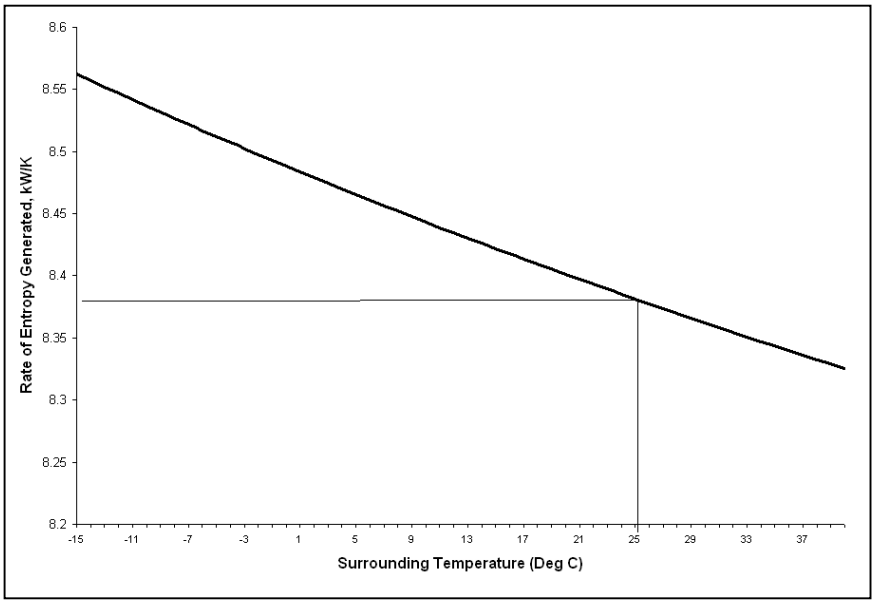


Figure 2. Parameterization Graph from Table Produced by EES

Sample Activity Using Interactive Software in Integrated Mechanical Systems

These activities were designed with the purpose of presenting to the student a relationship between the equations of motion and the moving objects that they modeled. These assignments included the range of topics covered in Integrated Mechanics II (i.e., Masses and Volumes,

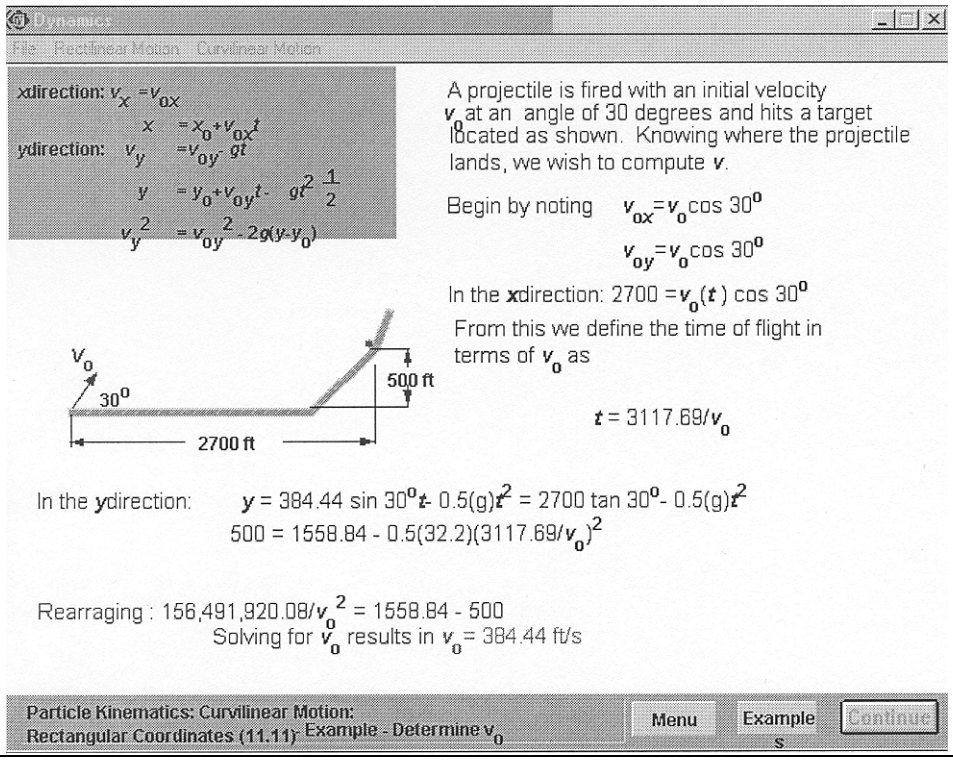
Particle Kinematics and Kinetics, Rigid Body Kinematics and Kinetics, Combined Stresses, Columns, and Rotations). A typical example was the simulation of curvilinear motion using various applications. For example, in one case the activity included the simulation of the motion of a projectile fired with an initial velocity at a prescribed angle aiming to hit a target located at a coordinate (x, y). Typical cases involved assigning problems, which were asked to be solved in the classical fashion (i.e., pencil and paper) and then transfer the information to the computers to see the simulation take place.

Sample Problem [11]

Find the initial velocity v_o if a projectile is fired at an angle θ and hit its target located at x and y. Let θ be 30^o, x = 2700 ft, and y = 500 ft. (Hint: solve v_o into its x and y components, determine the flight time in terms of v_o).

Activity

The previous problem was simulated using the interactive software. This is shown in the following figure, which is a screen copy of what the students observed, namely the simulation of the motion of the projectile together with a summary of the equations of motion.



Visual examples of this nature represented a remarkable teaching aid. The students had the opportunity to visualize and track the motion of the projectile as given by the equations of motion. Students normally don't get to see this in the traditional teaching mode of mechanics courses. The key feature of the software was that it was easy to learn and to use and that complex designs and advanced mechanical simulations could be developed and observed without extensive programming.

Sample Hands-On Activity

The purpose of these activities was to ask the student to design experiments, make actual measurements, and develop quick analyses. The assignments were given in a format such that after a set of guidelines were provided, the students were free to proceed however they considered appropriate. The following is an actual hands-on activity given to the students in Integrated Systems II during the spring of 1998.

Problem Statement

With your base group perform the following task: Estimate the COP and the heat rejected (to the kitchen) of a group member's refrigerator.

Hints: You need to estimate the amount of heat being removed from the food compartment. One possible way to get an idea of the rate of heat removal from the food compartment is to use a container filled with water at room temperature. Measure and record the volume of the water and the temperature of the water before you place it inside the refrigerator. Once the container is placed in the refrigerator, measure and record the change in temperature of the water per time interval, $\Delta T/\Delta t$, at equal time intervals (i.e., every 2-3 minutes). For this, use a long thermocouple wire and do not open the refrigerator door.

Use the following equations to estimate the rate of heat removal and the coefficient of performance, COP:

$$\dot{Q}_L = mc\frac{\Delta T}{\Delta t}$$

where

m = Mass of water (kg or lbm)

c = Specific heat of water (kJ/kg-K or Btu/lbm-^{o}R)

$$COP = \frac{\dot{Q}_L}{P}$$

where

P = Power input at the compressor of the refrigerator, (kW or hp)

To estimate the power input to the compressor of the refrigerator you can do several things: (1) Find the nameplate of the compressor and obtain the power. Be aware that this value is the "break-horsepower"; therefore, you must locate the efficiency for this motor size; (2) Call the vendor, or (3) Measure it (Not recommended for safety reasons).

Requirements

Prepare and submit a typewritten report with the following sections:

- Cover Sheet
- Problem Statement
- Theory Involved
- Experiment Design: Document how the experiment was set up and how the measurements were taken, step-by-step. List all of the assumptions used in the completion of this project (i.e., heat removal estimated is from the refrigerated space, but does not include the freezer while the compressor operates for both, the refrigerated space and the freezer; adiabatic refrigerator walls, or the heat conducted from the environment to the refrigerated space; efficiency of the compressor, etc.).
- Results: Report the COP, heat rejected, maximum possible theoretical COP, cost of running this refrigerator per unit time, and provide explanations.
- Conclusions

The reports produced by the students were simple in nature, but one could tell the level of reasoning that had gone into the completion of the tasks. Also, it was remarkable to see how the theory and practice came together in these simple assignments. Another fact was the realization by the students that measuring values was not as simple as imagined before the tasks. In regular

end-of-chapter problems most of the values are provided where the student is left to proceed to plug them into equations or find intermediate values in charts and/or graphs. In these hands-on simple projects, a different reality was presented to the student, and although the final results were in most cases off, the experience of trying to find out why the results were what they were was very illuminating for the student. Other activities included estimating the mass of air in the classroom, determining the convection coefficient from an 'on' light bulb to the environment, relating the heat transfer across walls to the feeling of the same energy transfer in one's hand, and expanding the gas inside a piston-cylinder arrangement.

Observations

The inclusion of simple examples, which required the students to use computers and hands-on approaches to solve engineering problems altered both the teaching and the learning experience. Computer software packages and hands-on experiments were used effectively for class delivery and independently by the students to solve problems and to further explore additional situations, conduct independent investigations, sometimes led by simple curiosity, generate and reduce data, and to complete assignments. In contrast to the classical blackboard/chalk delivery of lectures, the visualization tools (i.e., graphs, charts, simulations, schematics, etc.) as displayed in computer monitors, the set up of engineering problems using new computer resources, the rapid development of parameterization tables to evaluate alternative solutions, the measuring of variables in real time, and the sharing and questioning of ideas with peers, positively enhanced the learning experience. The use of these techniques transformed the classroom into a laboratory, sometimes virtual, sometimes real, where students used the technology to investigate, speculate, and verify their findings. Under this setting, more tangible connections between practice and theory were possible.

As a whole, students reacted positively to the use of software and hands-on projects despite having to spend more time than they would normally spend on a course. The students often projected that they welcome the integration of new technologies because they were learning something they considered valuable. In fact, in addition to the problem solving and visualization benefits, in the process of completing tasks the students developed other skills, such as how to use the computers to write reports, create tables, scan, develop charts and graphs, analyze and evaluate information, as well as to how organize their information, make presentations, and to socialize professionally with their peers.

Although the use of computers allowed students the independent discovery and the exploration of different solutions and approaches, the instructor-student communication was also superior. The fact that both students and instructor were dealing with something new and not free of problems allowed for better and more open channels of communication. The interactivity nature of the technology increased student engagement.

It was observed that students were better prepared for tests and in general performed very well in the courses and in subsequent ones. A sense of confidence was observed in the student when they were given the resources to try "new" things. However, besides putting significant amount of effort, there were some students who were still unable to follow the process and/or use the

technology adequately. This was mainly true for those students with poor academic backgrounds.

Lessons Learned

Of the lessons learned, the first and foremost was the fact that the teaching experience was positively enhanced when appropriate technologies were incorporated into the instruction process. However, the inclusion of such techniques into courses was not inexpensive in terms of equipment, software, and other costs, and in terms of faculty time. The development of course material took a significant amount of time on the instructor's part. Learning how to use the technology before teaching it to others was a challenge. Each assignment had to be carefully developed as to eliminate technical errors and to stimulate critical thinking. For this reason, it was learned that the overall redesign of course delivery had to start small and be kept simple.

Because of the effort involved by both students and instructors, it was necessary to have class sizes restricted to fewer than 25 students. This was particularly the case because of the problems that were often encountered when using computers or other electronic gadgets (i.e., software not running properly, slow computers, uncalibrated probes, loose wires, safety issues, noise, etc.) and because of the time commitment and consequences of using collaborative learning pedagogies.

Classrooms had to be adequately furnished to allow for the proper delivery of the course material. However, technology by itself was not enough. Faculty had to be trained to put the equipment to good use. For this to happen, the participating faculty needed to have the support of the administration. Leadership was the critical component.

Finally, technology integration was a slow, time-consuming process where different levels of support and talents were needed. Redesigning courses to include technology and hands-on project was a collegial process. Course content, problems, lessons learned, recommendations, frustrations, drawbacks were often discussed with colleagues, administrators, and professionals with expertise in technology. Such interactions were very valuable.

Post Participation Assessment

Each participating campus was charged with conducting evaluation and assessment tasks pertaining to their programs. The purpose was to validate progress toward attainment of program objectives and/or to revise ongoing processes. At TAMUK methods such as focus groups, journals, attitudinal surveys, and quantitative data comparing performance between comparison groups were used to assess the effectiveness of the program. Surveys conducted noted that participating students were pleased with the access to computers and design projects, quality of FC-participating faculty, the enhanced relationship between students and instructors, the "friends-and-family-like" atmosphere, and the collaborative learning aspects of the program [12].

Grade-Point-Average comparison between the FC-participating students and the traditional students did not produce significant differences. However, a remarkable trend was found when

FC students' performance was tracked in upper division courses. When the final grades of students participating in the Second Year Integrated Curriculum were compared to those of traditional students enrolled in the same upper division courses, with the same professor, and same semester, in 15 out 17 courses, the FC-participating students significantly outperformed traditional students. It was also found that FC-participating students were retained at higher rates than traditional students [12].

Conclusions

Overall, the use of equation solvers, interactive software, and hands-on projects in the classroom was a positive experience. Without a doubt, the students who participated in these courses were better prepared for subsequent courses and performed much better as recounted by instructors who taught them in upper level courses and reported in assessment reports. In general, most of these students knew how to apply fundamental principles, had a better ability to identify and define problems, and knew how to evaluate alternative solutions. In upper level courses, these students gave the best presentations and wrote the better reports and were able to use computers and other modern technology for setting, solving, and presenting problems. Assessment results indicated that retention rates among the students who participated in the program were higher than in the traditional group. Also, it is noteworthy to point out that most of these students had enhanced social skills as compared to when they first arrived and to others who did not participate in the program. It is known that some students who participated enrolled in graduate school, but more information is not available to document the impact the courses had in individuals' lifelong learning objectives.

Bibliography

1. Smith, K. and A. Waller, "New Paradigms for Engineering Education," *Proceedings of the 1997 Frontiers in Education Conference,* Pittsburgh, PA. Nov. 1997.

2. http://www.foundationcoalition.org/

3. Corleto, C.R., Kimball, J.L., Tipton, A., McLauchlan, R.A., 1996, "The Foundation Coalition First year Integrated Engineering Program at Texas A&M University-Kingsville: Development, Implementation, and Assessment," *Proceedings of the Frontiers in Education Conference*.

4. Heenan, W., McLauchlan, R.A., 1996, "Development of an Integrated Sophomore Year Curriculum," *Proceedings of the Frontiers in Education Conference*.

5. Froyd, J.E., "An Integrated, First Year Curriculum in Science, Engineering, and Mathematics: High-Context Curriculum Via Low-Context Faculty," 23rd UPADI Convention, 16th Pan-American Congress on Engineering Education, Mexico, 1994.

6. Corleto, C.R., Stewart, J., Tipton, A., 1997, "Evaluation of a First-Year Integrated Engineering Curriculum," *Proceedings of the Frontiers in Education Conference*.

7. http://www.fchart.com/

8. Breeden, J.B. and G.H. Staab, 1996, "Interactive Software to Accompany Beer/Johnston Vector Mechanics for Engineers 6th Ed," McGraw-Hill.

9. Morhmann, Nelwyn, 1998, "*Integrated Thermal Systems II – Technology Enabled Learning Assignment # 6: Entropy Generation"* Texas A&M University-Kingsville.

10. Cengel, Y.A and M.A. Boles, 1998, Thermodynamics: An Engineering Approach, 3rd Edition. McGraw-Hill.

11. Beer, F.P., and R. R. Johnston, Jr. 1997, Vector Mechanics for Engineers - Statics and Dynamics, 6th Edition. McGraw-Hill.

12. Weckman, G.R., McLauchlan, R.A., Crosby, J., 2001, "An Assessment and Evaluation of an Integrated Engineering Curriculum," *Proceedings of the Frontiers in Education Conference*.

MARIO A. MEDINA
Mario A. Medina is an assistant professor in the Civil, Environmental, and Architectural Engineering Department at the University of Kansas. Prior to joining the faculty at the University of Kansas, Dr. Medina was an assistant professor in the Mechanical and Industrial Engineering Department at Texas A&M University at Kingsville. He chaired the Center for Innovation and Teaching Excellence and was an active member of the Second Year Curriculum and Upper Division Teams of the Foundation Coalition. At the University of Kansas he was department ambassador to the Center for Teaching Excellence. He received his Ph.D. from Texas A&M University in mechanical engineering with specialization in the thermal analysis of energy systems.