Using a Learning Process Model to Enhance Learning with Technology

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INTRODUCTION

Two years ago professional engineers from across the northwest met in Coeur D'Alene, Idaho for their regional meeting. As part of the program, they participated in an interactive session where they identified the eight most important attributes in new employees. Representatives from business, government, and education required employees who excelled as:

1. Quick Learners
2. Critical Thinkers
3. Problem Solvers
4. Communicators
5. Professionals Knowledgeable in their Field
6. Team Players
7. Self Starters
8. Creative Thinkers

This list reflects the dynamic nature of the nation's workplace in an era of ongoing technological change. Unfortunately, it cannot be assumed that students possess this set of skills when they enter college. In fact, critics of higher education contend that many college graduates have only minimal development of their abilities in these areas [1]. The pedagogical approach described here is intended to fortify these learning and problem solving skills early in the curriculum [2].

LEARNING PROCESS MODEL

The authors have used the Learning Process Model outlined below to teach students at the University of Idaho for the past three years [3]. This model is based on active learning principles such as one minute papers, journal writing, self-discovery, self-assessment, and cooperative learning [4]. The model consists of the following steps.

1. Evaluate the students' proficiency with the base concepts needed to master the new concept and the students' comprehension of a background reading assignment. Additional exercises should be provided as necessary to build this proficiency.
2. Introduce a model of the new concept for students to explore.
3. Give students a set of critical thinking questions for each concept model that will guide the students toward an understanding of the concept as they examine the model.
4. Organize a set of discovery exercises that allow groups of 2-3 students to apply the concept to new situations.
5. Assign a set of problem-solving projects that require students to transfer, transform, and synthesize the new concepts they have learned.

When using the model, the student focus is to experience self-discovery, ask relevant critical thinking questions, learn faster, and practice group problem solving skills. Alternatively, the focus of faculty members is to let students "try it", to ask questions rather than give answers, to facilitate cooperative learning, and to motivate students with interesting problems.

ROLE OF TECHNOLOGY

Computer technology can be used to enhance the learning process model. The keyboard provides an excellent environment for students to explore and experiment with new ideas. Likewise, the computer screen provides immediate visual feedback which the students can use to assess their reasoning. The computer screen also serves as a record of students' thought processes which can be unobtrusively monitored in real time while student groups are engaged in critical thinking, discovery, or problem solving exercises [5].

By coupling computer technology with cooperative learning, students strengthen communication, leadership, and decision making skills. Many questions are then resolved by student peers rather than by the instructor. This frees the instructor to move between groups, continually assessing their progress and intervening only when his/her expertise is really necessary [6].

The primary software tools used in this course are DOS and PC:SOLVE, a modeling language by Pacific Crest Software. PC:SOLVE consists of seven tools for solving problems. These tools include: (1) a mathematical toolbox, (2) a relational data management tool, (3) a graphing system, (4) a modeling language, (5) a report writing tool, (6) a statistical analysis system, and (7) a high-level programming language. All seven tools are accessed from a "scratchpad" environment which is as easy to use as a calculator. Results of calculations appear in an output window located above the scratchpad. PC:SOLVE allows users to easily create, manipulate and analyze data; quickly generate graphs; build and explore models; design applications programs; and create short reports. PC:SOLVE is similar to other software tools such as MATHEMATICA, MATLAB, and MATHCAD.

CLASSROOM SITUATION

The learning process model is used repetitively throughout an introductory engineering course at the University of Idaho. Typically 40 students participate in this course each semester. The course carries three credits and consists of three fifty minute periods per week in a classroom equipped with a large-screen VGA projector. Once or twice a week students are taken to a computer lab with 16 PCs for the second half of class. Course topics include DOS file management, engineering economics, functional graphing, descriptive statistics, curve fitting, schedule planning, data management, numerical differentiation, numerical integration, structured programming, software documentation, library management and design methodology.

Students work in groups of 2-3 on weekly homework assignments. Each group submits one assignment and all participants receive the same grade. Homework is worth 30%, class participation is worth 10%, and individual performance on the midterm and final exams is worth 60% of the course grade. Both exams are scheduled in the PC laboratory, and both exams require students to use the computer as a problem solving tool.

PREASSESSMENT

Before students can learn a new concept, it is necessary that they have a thorough understanding of the base concepts which underlie the new concept. For example, before introducing numerical differentiation as an engineering analysis tool, students should understand how to create a domain, define a functional relationship, plot ordered pairs, use point-slope and slope-intercept formulae, and evaluate limiting behavior.

One way of assessing this proficiency would be to ask students to plot the one-dimensional response of a shock absorber which is given by y = EXP(-t) COS(2 π t) over the domain 0-2 seconds, where y is in inches. If a group of students were using PC:SOLVE, their solution in the scratchpad might look like the following.

```
t = DOMAIN(0, 2)            ;time, (sec)
y = EXP(-t)*COS(2*pi*t)     ;position, (inches)
yrefline = 0                ;reference line
GLINE(t,y)
```

This model produces the graph shown in Figure 1. The students' understanding could be further queried by asking them to write the equation of the tangent line at 1 second or to report the roots of this function.

CONCEPT MODELING

A concept model can be formed using language, physical objects, mathematics, or pictures. Good concept models illustrate key issues and can be easily transformed to study other situations. A concept model for numerical differentiation, which further examines shock absorber response.

```
t    = DOMAIN(0, 2)             ;time, (sec)
y    = EXP(-t)*COS(2*pi*t)      ;position, (inches)
dydt = DERIVATIVE(t,y)          ;velocity, (inches/sec)
yrefline = 0
GLINE(t, y, dydt)
```

This model produces the comparative graph shown in Figure 2.

CRITICAL THINKING

To get maximum value from a concept model, students need a set of critical thinking questions to guide them through their exploration. For the purposes of our methodology, we define critical thinking as a way to explore ideas by identifying the important issues, and then asking key questions related to those issues. Critical thinking questions may be used to get students to think about the general concept, exceptions to the general rule, boundary conditions, logical extensions to the concept, and opposing concepts.

Critical thinking questions can be divergent, convergent, or directed. Divergent questions highlight the direction that the students' inquiry should be taking but make students choose their approach from a variety of possibilities. Convergent questions help students converge on a particular idea. Directed questions which tend to have a single answer should be used if students become too frustrated.

Examples of critical thinking questions for numerical differentiation are given below.

- What is the relationship between a function and its derivative? (Divergent)

- What is the relationship between a derivative and the slope of the tangent line? (Convergent)

- What is the slope of the tangent line at 1 second, and how does this compare with the derivative at this point in time? (Directed)

- How can you validate that a numerical derivative is correct? (Divergent)

- How do you know if you have enough points in your domain when using the derivative function? (Convergent)

- What happens to the accuracy of the derivative if you decrease the number of points in the domain? (Directed)

DISCOVERY EXERCISES

Students build mastery with new concepts by applying them to different situations. In-class exercises with groups of 3-4 students provide an excellent vehicle for students to test and expand their understanding. The role of the instructor in this step is to assess the students' proficiency and to ask timely critical thinking questions. Students are encouraged to look up the answer, consult a team member, or try it out on the computer before they ask the instructor. Cooperative learning is a valuable asset in this step because the students have a pool of thinking and learning skills to draw on, in addition to their own, and the effort, excitement, and frustration can be shared.

If students are working with SOLVE, the instructor has an extra means for assessing their progress: the "paper tape" generated in SOLVE's output window. The paper tape records the students' thought processes--the directions they headed, the side trips and dead ends, the additional concepts explored, and the speed with which they grasped the key concept.

Students should be given simple exercises to start with, so they can become familiar with and come to like this method of teaching without too much frustration. Students should be forced to think, but not to the point that they become overwhelmed. As time goes by, they should be given increasingly more complex problems. The amount of frustration needs to be continually monitored--some frustration is good, and provides motivation to find a solution and resolve the frustration. Too much is counterproductive--if too frustrated, students can become convinced they'll never find a solution, lose their motivation, and give up.

In the example of numerical differentiation, students might be asked to graph the acceleration of the shock absorber as a function of time and provide estimates of the first three times that the acceleration is zero. A more difficult exercise would be to plot the response in state space (acceleration versus velocity) and to verify that the trajectory tends toward stable equilibrium. The solution to the latter exercise might be the following.

```
t = DOMAIN (0,5,200)       ; time, sec
y = EXP(-t)*COS(2*pi*t)    ; position, inches
v = DERIVATIVE(t,y)        ; velocity, inches/sec
a = DERIVATIVE(t,v)        ; acceleration, inches/sec^2
GLINE(v,a)
```

This model produces the graph shown in Figure 3.

PROBLEM SOLVING ACTIVITIES

Outside of class, student teams work together on problem solving projects that require them to synthesize the concept models explored in the laboratory period. These assignments frequently ask students to find applications for their new concepts. Example projects include:

- writing a batch file for a personal application;

- tabulating, analyzing, and graphing course assessment data compiled by fellow students;

- developing and testing an economic model which will help to determine whether a personal computer is a cost effective investment;

- using a library of database functions to create an academic career plan which outlines how to schedule all remaining coursework so that all pre-requisites are satisfied; and

- modeling and building a balloon rocket which will travel a one-dimensional course in a minimum amount of time.

CONCLUSIONS

A five step learning process model has proven effective in teaching graphical, statistical, and numerical analysis topics to pre-engineering students at the University of Idaho. Active student participation in the classroom and "hands-on" involvement in a laboratory setting are key elements in this pedagogy.

In course evaluations all students agreed with the statement that concepts and problem solving methods learning in the course could be applied in other classes. In fact, more than two thirds of the students indicated that they had voluntarily used software tools from the course in completing homework assignments for other classes. The selected comments which follow attest to the success of the instructional methods used in this course.

- At first I didn't like the way the instructor wouldn't answer a question. Instead he would ask you another question right back. However, in the end I found that way of helping to be most effective in making me think.

- You learn more in courses where you take part in class.

- The in-class computer exercises with the large screen projector were intimidating at first but in the end answered all my questions and more.

- I was surprised how well students worked together. This made the course more interesting and more fun.

REFERENCES

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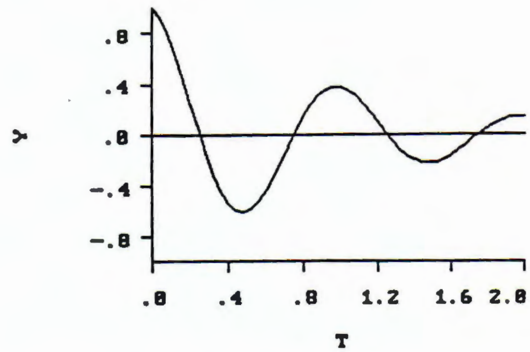

Figure 1. Graph of Shock Absorber Response.

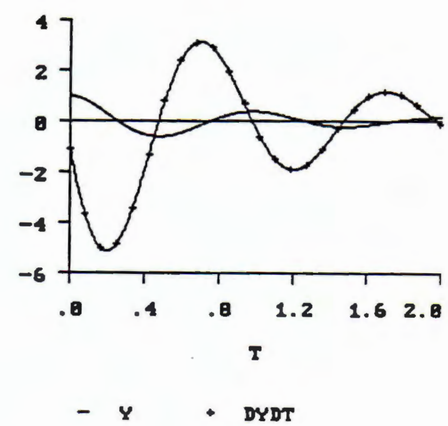

Figure 2. Graph of Shock Absorber Position and Velocity as a Function of Time.

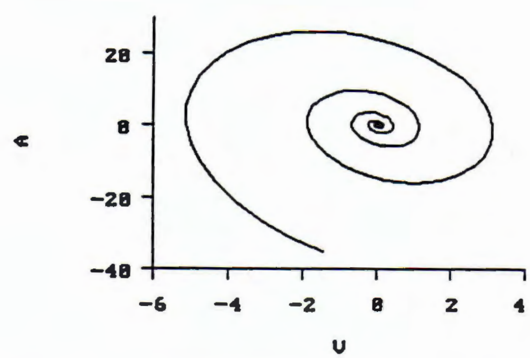

Figure 3. Graph of Shock Absorber Response in State Space.