Problem Solving and JIT Delivery of Skills In a First Year Engineering Technology Course

Andrew C. Kellie¹ and Michael Jordan²

Abstract

This paper reports on implementation of problem solving based instruction within a first year environmental engineering technology course. Class structure employs a combination of formal instruction, team-based problem solving, and just-in-time delivery of instructional content. Unlike other approaches to problem solving based instruction, the method suggested here employs a mix of traditional instruction, and on-going development of computer skills, in an organizational structure similar to that found in a small consulting firm.

Course organization is facilitated by a scheme that provides a two hour class period and a three hour lab period each week. The class period provides the necessary time for student presentations of the previous week’s lab assignment and a brief introduction to the topic of study for the coming week. Assignments are presented to each team in the form of a memo to which are attached field data or drawings. Student teams must respond by memo, letter, or report within the time frame required. Results must be supported by computations, graphs, and other documentation.

Three years of experience with the instructional format described above has shown a number of things useful in planning similar courses. First, course structure has a definite role in helping students to organize learning. Second, outside instructors provide motivation as well as instruction and should be an integral part of this type of teaching. Third, careful monitoring of team interaction is important to ensure that each team member both participates in and understands the solution. Finally, problem solving based instruction provides an excellent opportunity to develop in the student the confidence and pride fundamental to success both in college and in the workforce.

Introduction

The integration of lecture and laboratory exercises is an essential component of effective teaching. The laboratory environment provides a means for combining theoretical understanding with practical application. This format can be particularly effective in engineering technology courses where practical application of theoretical material is central to instruction.

¹ Professor, Department of Industrial and Engineering Technology, Murray State University, Murray, KY 42071
² Assistant Professor, Department of Industrial and Engineering Technology, Murray State University, Murray, KY 42071
Apart from assisting in the learning process per se, laboratory exercises also function to introduce the student to the thought processes, analysis methods, and data presentation techniques used by engineering technologists. If an element of teamwork is built into the laboratory session, team members have the opportunity to function in much the same manner as they would on the job. Hence, it is possible to identify a socializing function for laboratory-based learning.

During the past eight years, one of the authors (Kellie) has taught a basic environmental engineering technology course to first-year students. The introduction of a laboratory component was tried in the second year in which the course was taught, and the format of the course gradually changed from a predominantly lecture-based course to a primarily laboratory-based learning experience employing just-in-time delivery of techniques needed to solve laboratory assignments. At the same time, much of the responsibility for learning has been shifted to the student.

With the changes just noted, it was felt appropriate to review course structure and content and to address a number of questions felt to impact both the course itself and the student learning experience. Specifically, we investigated the following:

(a) What role does a lecture component provide in the current instructional scheme?

(b) How do students perceive the use of just-in-time delivery of instruction, particularly when guest instructors are employed?

(c) How might the course be modified further to enhance the first-year learning experience?

**Previous Work**

The subject of the first-year learning experience has been addressed by a number of authors. Pendergrass, *et al.* (2001) describe the development at the University of Massachusetts Dartmouth of an integrated first-year program that they termed IMPULSE. The IMPULSE program employed integrated instruction in English, physics, calculus, chemistry, and engineering; used both active and cooperative learning methods; relied on block scheduling of students to maintain student grouping; and expedited learning by student and faculty teamwork. In addition, IMPULSE students had available to them a specially designed technology-oriented classroom.

In discussing course structure, Pendergrass, *et al.* relied on careful sequencing of topics in calculus to facilitate use of that subject in physics. The first chemistry course was revised to “keep student loads reasonable”, teaching assistants were used extensively, and IMPULSE students were even housed together to facilitate a sense of community. One point of particular interest to the authors of this paper was the use of the basic engineering course to teach Computer Aided Design (CAD) as a course component.

Comparison of the IMPULSE students with two control groups showed that the IMPULSE students earned more credits, attempted more credits, and earned more quality points than did the controls. In addition, the percentage of IMPULSE students taking final exams in physics, chemistry, and calculus were higher than control groups as were the exam scores earned by IMPULSE students.

Turner (2001) discussed the use of project-based instruction to teach computing techniques at the U.S. Naval Academy. In his research, he notes that there appears to be a “performance penalty” as students attempted to integrate material from different courses that often appear to be independent areas of study. Turner (2001) used MATLAB as means to expedite learning while shifting emphasis from programming details, and employed a series of five different projects to replace the traditional...
instructional method formerly used in the course. Instruction in programming per se was shifted to a “just-in-time” format.

In discussing reaction to the changed course format, Turner (2001) noted that students criticized the lack of a common text. Further, students had difficulty with the first assignment (as Turner noted, perhaps because it was the first), and lack of what were seen as “more realistic” problems. On the whole, Turner (2001) felt that the new format was a distinct improvement on traditional teaching of scientific computing.

Whiteman and Nygren (2000) discuss the use of mathematical assistant software in instruction at the U.S. Military Academy. The use of such software allows for comparison between analytical results and experimental observations for predicting, refining, and designing solutions for engineering problems. This can directly impact standard, accepted methods of design and significantly benefit the overall learning process. Whiteman and Nygren (2000) note that a discrepancy appears to exist between methods employed in engineering practice and those taught in engineering education. While the use of mathematical assistant software in engineering practice has become the norm, the use of such in education has been less pronounced.

Setting the premise for the incorporation of mathematical assistant software into the classroom, Whiteman and Nygren (2000) review three learning models. These include the Scientific Learning Cycle (based on work by Piaget), the Kolb Learning Cycle, and the Process Education learning model. Whiteman and Nygren (2000) note that each learning model includes an application and problem solving phase for which mathematical assistant software offers the capability to readily obtain results for many different problems. This shifts the focus from the mechanics of mathematics to other more uncertain aspects of problem solving. For example, students might run different solution scenarios based on a single mathematical model.

Use of mathematical assistant software does not diminish the need for understanding of concepts and methodology. Reduced is the time required for tedious and complex calculations, allowing analysis of more complex problems and enhancing the relevance and motivation of the student. Whiteman and Nygren (2000) do note disadvantages to such software use, however, including reliance on trial and error problem solving rather than engineering analysis. They note that a balance may be achieved through testing which focuses on “critical thinking, problem formulations and interpretation of results, along with the ability to apply problem solving skills.”

Wolf (2001) offers a discussion of engineering technology (ET) education and issues associated with defining curricula for ET programs. Based on his work for Boeing Corporation during a recent sabbatical, Wolf (2001) compares Boeing’s strategic response in manufacturing to that of current trends in education, and finds current education structures lacking. In particular, Wolf (2001) notes that “the cohort of students to whom the investment value [of an education] is paramount has been growing more rapidly than that of the so-called traditional students.” He describes this cohort as including transfer students, part-time students, and degree-completion students who he sees as being ill-served by the traditional four-year, full-time, day-school block. Indeed, Wolf (2001) describes the students with whom he works as having an average of 2.4 transcripts from other institutions at the time of admission to the ET program.

Methods and Results

Based on the foregoing work, the authors designed an evaluation of a single instructional module in a traditional fundamental environmental engineering technology course. Unlike the structured learning situation described by Pendergrass, et al. (2001), Murray State University makes no formal attempt beyond specification of prerequisite courses to schedule integrated math, physics, and
chemistry coursework. Nor is it feasible to move students through the curriculum in a cohort. Indeed, the learning environment strongly resembles that described by Wolf (2000) in which varying percentages of each class consist of transfer students, non-technology majors, and non-traditional students.

Despite the constraints just noted, however, it still was felt possible to employ such techniques as team-based problem solving, just-in-time delivery of instructional content, and use of mathematical modeling within the course as described. Unlike the situation described by Turner (2001), students do have access to a common text, and, in common with the emphasis on problem solving, the organizational structure which has evolved is similar to that found in a small consulting firm.

Course organization is facilitated by a scheme that provides a two hour class period and a three hour lab period each week. The class period provides the necessary time for student presentations of the previous week’s lab assignment and a brief introduction to the topic of study for the coming week. The curriculum is designed so that mathematical modeling based on spreadsheet software is used in a manner that requires use of progressively more advanced computational methods as the semester progresses. The techniques necessary to solution of the current assignment are presented just prior to the need for such techniques in lab assignments. In order to take advantage of the mathematical modeling, computational work commonly requires student evaluation of multiple solution scenarios in an attempt to generate logical solution process, rational thought, and an analytic approach to problem solving.

Assignments are presented to each team in the form of a memo to which is attached field data or drawings. Student teams must respond by memo, letter, or report within the time frame required. Basic instruction necessary to solution of the problem is presented, but specifics of the problem to be addressed are left largely to the students. For some exercises, additional background material may be posted on the course web site. Results must be supported by computations, graphs, and/or other documentation.

A good illustration of the type of assignment given in the course under discussion is the unit on heat transfer that is normally taught midway through the semester. There are three pedagogical objectives to this exercise: (1) develop ability to apply a theoretical concept to an applied problem, (2) introduce the idea of using construction drawings to obtain data needed in solution, and (3) further develop ability in mathematical modeling of alternative solution scenarios. The theoretical basis for the lab assignment is the universal heat transfer equation

$$Q = \frac{1}{\Sigma R} A \delta t$$

where

- $Q$ = heat transfer,
- $\Sigma R$ = total resistance to heat transfer,
- $A$ = surface area, and
- $\delta t$ = temperature difference across the surface.

This equation is presented in class prior to the project assignment. Solution of the equation is demonstrated by computing heat transfer through a hypothetical wall. Material R-value is discussed, and the concept of seasonal heating degree days is also explained. Students are next presented with a memo requesting computation of seasonal heating cost for three construction
alternates for a simple residence. The memo is accompanied by a set of construction drawings and a database of R-values for typical construction materials. Additional material on heat transfer is posted on the class website prior to the laboratory session. It should be noted that the solution required of the students goes beyond calculation of heat transfer; the quantity of heat transferred (lost) must be replaced by heating, and the seasonal heating cost computed for each of the three construction alternatives provided to the students.

Past experience with this exercise has shown that reading and working with construction drawings has been the most difficult part of the exercise for students. This is probably because basic team work and mathematical modeling abilities have already been developed at this point in the semester, thus minimizing the “transfer cost” noted by Turner (2001). To facilitate understanding of construction drawings, one of the authors (Jordan) explained the conventions of elevations, floor plans, and sections and serves as a resource person to answer questions. Interestingly, anecdotal observations show that students have little difficulty in obtaining areal data from the drawings, but experience significant difficulty in reading the sections.

Beyond already established guidelines for developing mathematical models and their use in technical presentations, solution is left primarily to the students. Students must work in groups of two, with selection of partners being the responsibility of the students. A common report must be submitted. In all, some five hours of class and lab time are allocated to this exercise. This includes three hours to four hours of time in the computational computer lab, much of which appears to be used by the students to review and discuss the construction drawings. The use of a single mathematical model to analyze alternative solutions as proposed by Whiteman and Nygren (2000) was employed by the students without any prompting.

In an attempt to gauge student reactions to this exercise, the authors prepared and distributed a questionnaire to students in the Fall, 2001 semester. The purpose of the questionnaire was to rate the effectiveness of the instruction involved. Because the research described herein involved human subjects, the questionnaire and an informed consent document for research participants were reviewed and approved by the Institutional Research Board (IRB) at Murray State. A student proctor administered the questionnaires in the absence of the authors, and the questionnaire contained no information by which the person preparing the questionnaire could be identified. Eighteen questionnaires were returned. A summary of student responses is shown in figure 1. The questions used, together with the average response and standard deviation thereof, are shown in Appendix A.

**Discussion and conclusions**

In reviewing student responses, a number of things are apparent. In general, students feel that they understand the objectives of the exercise, are confident of their mathematical modeling ability, and claim to understand the theoretical concepts involved. The students appear to value the team approach to problem solving required in the exercise, and feel confident of their ability to work with construction drawings.

Several of the responses from the questionnaire, however, merit more detailed review. First, questions 4 and 9 are primarily concerned with student ability to independently pursue the work assigned. Based on the average response to question 9, completion of the work with less formal instruction was not favored by the class. Examination of individual responses, however, indicates that 3 of the 18 students responding would have preferred an attempt to solve the problem on their own. Question 4 dealt with student confidence in solving the problems posed based on the supplemental material provided on the class website. In general, students felt that the material enabled self-instruction.
Second, questions 11 and 12 dealt with integration of material across the curriculum. The average response to question 12 indicated that students found math coverage sufficient to solve the problem posed. However, the response to question 12 showed that few students had studied heat transfer in other courses. As explained previously, the academic background of students enrolled in the basic environmental engineering course is decidedly different from that described by Pendergass, et al. (2001). Because of this, student math ability is of major concern to the faculty.

Faculty perceptions of the exercise were somewhat different than those expressed on the questionnaires. First, at the time the exercise was conducted, one of the authors (Kellie) felt that the theoretical explanation had not been fully sufficient and that instruction should have included additional student-worked mathematical examples. This perception was based on questions posed by students during the laboratory period. However, it is possible to conclude that the learning desired was indeed taking place as students developed questions about theoretical concepts as these were applied to the problem at hand. In essence, students were in all likelihood accommodating to their individual approaches to learning the material.

Second, students’ perception of their ability to read construction drawings exceeded that of the instructors’ perception of student ability. Instructor perception was based on materials shown in a section, but not included in the heat transfer computation. Unlike the freshman engineering course described by Pendergast, et al. (2001) the course described herein contains no CAD or drawing instruction beyond that presented in this single exercise. In short, lack of practice in reading construction drawings—together with little exposure to the level of detail provided thereon—may explain student confidence expressed in the questionnaire.

The first question posed in this paper was: What role does a lecture component provide in the current instructional scheme? In responding, it is the authors’ conclusion that the primary function of the lecture component in the exercise under discussion was that of providing a learning structure. In this exercise, students were able to build further learning on the basic structure provided by lecture without additional formal instruction. However, it must also be recognized that the availability of the instructor to respond to questions during the lab session, and the availability of additional instructional materials, provided an alternative to formal lecture-based instruction.

The second question posed by this research was: How do students perceive the use of just-in-time delivery of instruction, particularly when guest instructors are employed? In general, we conclude that the students have responded well to JIT instruction based on their perceptions of being able to complete the work assigned. In this exercise, the guest lecturer provided a significant block of instruction. Hence, the authors conclude that this method of instruction was at least as effective as instruction provided by the regular professor. The students appeared to be comfortable with the guest lecturer based on the questions posed and the student-instructor interaction that developed.

The third question posed by this research was: How might the course be modified further to enhance the first-year learning experience? Based on the research reported above as well as observations of the results of similar laboratory projects, the principal author intends to modify the course described above to further limit the amount of lecture while at the same time increasing the amount of individual effort required of students in the course. Additionally, access to supplemental material on the class web site will be expanded.

In conclusion, the research above demonstrated to the authors’ satisfaction the importance of team-based problem solving as an important learning strategy. At the same time, it is also apparent that for some—and possibly most—students the lecture component of a course does continue to provide a valuable function in helping the individual student to develop a structure from which to begin the understanding of concepts basic to his or her profession.
References Cited


Appendix A—Student Questionnaire with Mean & Standard Deviation of Responses (scale 1-5, Agree—Disagree)

1. The objectives of the Heating Cost Analysis Project were clearly presented. 4.3 +/- 0.73

2. The theoretical basis for the universal heat transfer equation was explained in sufficient detail to enable me to apply it in the project. 4.4 +/- 0.70
3. The concept of degree days was explained in sufficient detail to enable me to apply it in the project. 4.2 +/- 1.00

4. The supplemental reading material supplied with the assignment enabled me to teach myself what I needed to know to complete the project. 3.8 +/- 0.94

5. Previous instruction prepared me sufficiently to complete the spreadsheet detailing the heating cost analysis. 4.1 +/- 0.94

6. The construction drawings were discussed in sufficient detail for me to understand them. 4.2 +/- 0.94

7. Additional discussion of building construction and/or a visit to a building actually under construction would have helped my understanding of this assignment. 4.0 +/- 0.97

8. After the discussion in class, I understood how to obtain the areas of the walls, ceilings, windows, and floors for use in heat transfer calculations. 4.6 +/- 0.70

9. Less instruction would have been better. I would prefer to complete this project by simply being provided with a project statement and resource materials. 2.1 +/- 1.4

10. Because I worked with another person on this project, I understood the project better than if I had done all the work myself. 4.2 +/- 1.5

11. The material in the Heating Cost Analysis Project was familiar to me because I had studied the subject in other courses such as Physics. 2.7 +/- 1.32

12. The mathematical techniques required for the Heating Cost Analysis Project have been covered in sufficient detail in my first year mathematics course. 4.4 +/- 0.78

13. Additional discussion of the thermal properties of building materials would have helped develop my understanding of heat transfer. 3.6 +/- 1.2

14. After in class discussion, understand investigate and obtain the thermal ratings of building materials and I understand the relevance of this information as pertains to thermal energy transfer. 4.2 +/- 0.73

15. The Heating Cost Analysis Project has interested me in Architectural Solar Design. 2.8 +/- 1.1

16. The study of heating cost analysis is an important component of the study of building technology and should be further emphasized in the building technology curriculum at Murray State University. 4.1 +/- 0.73

17. I would like to be involved with further similar projects regarding environmentally friendly design studies in my other building technology classes at Murray State University. 3.8 +/- 1.1

18. As a result of my involvement with this project, I have become more aware of concepts pertaining to solar design as it relates to the built environment. 4.1 +/- 1.0