Int. J. Engng Ed. Vol. 11, No. 6, pp. 406–414, 1995
Printed in Great Britain.

0949-149X/91 $3.00+0.00
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A New Approach to Teaching a Required Technical Course*

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A new approach to teaching a technical course to undergraduate students in a four-year B.Sc. engineering or engineering technology curriculum is described. The method, based on the Kolb learning cycle, involves: (i) incorporating the findings of undergraduate research into the class room; (ii) an interactive tutoring section; (iii) a new method of grading; and (iv) a progressive class evaluation. The paper describes the effectiveness of an interactive tutorial session, whereby students under the supervision of the instructor can meet during lunch at least once a week in a relaxed atmosphere to solve and discuss homework problems. A method of class evaluation conducted approximately three times during the semester will dictate the pace of the class. The overall effectiveness of this teaching technique, as measured by a new term 'sincerity index' and by the traditional students' rating of teaching effectiveness (SRTE) scores, reveals a significant rise in the effectiveness of the instructor. The motivation level of the students was high, as reflected in the number of students attending the voluntary tutorial session and their final grade in the course.

INTRODUCTION

WHEN I first taught heat transfer to mechanical engineering technology students, I found the students had a variety of backgrounds, preparedness and abilities. I soon discovered that the class was quite different from the regular engineering class that I had been used to teaching. The students had different learning styles and very different abilities to grasp what was being taught. Many of the students lacked the mathematical background of most engineering students. The Pennsylvania State University at Harrisburg, an upper division campus, gets students from various Commonwealth campuses with varying degrees of preparedness. We also have a high percentage of non-traditional 'back-to-school' and part-time students.

Non-traditional students are not recent high school graduates. Because of the recent economic downturn, older students, some with a baccalaureate degree in another discipline, come into the program to seek new skills which they believe will make them more competitive in the market place.

The Student Rating and Teaching Evaluation (SRTE) questionnaire administered at the end of a semester, originally designed for the teacher to gauge how well the students have coped with the class and what changes the instructor should make, is now used for promotion and tenure. There are those who feel that the SRTE is usually turned into a vendetta by students who did not do well or get a grade they felt they deserved, or as a reward by those students who did well. Some argue that the SRTE is usually a reflection of the class grade. The point is, instructors are not able to use that evaluation to improve themselves. Furthermore, the present class will not benefit from any improvement derived from that evaluation. Each semester we face a different set of students with a different learning style and level of preparedness.

According to Claxton and Ralston [1], students have different learning styles, different preferences in the way they respond to and use stimuli in the context of learning. Felder and Silverman [2] enumerated 32 different learning styles and discussed ways in which educators could meet the needs of different types of learners. Feiz and Catania [3] developed a method that increases the learning ability of students in a technical mathematics course. The method was based on Kolb's learning cycle. Kolb's [4] cycle identifies four learning styles based on the ways students perceive and process information. Feiz and Catania [3] gave special consideration to the concrete experience stage of the Kolb cycle and discovered that supervised hands-on experience with the concepts facilitated the transition from student as an observer to student as an active participant. Stice [5] also discusses Kolb's model and its potential advantage in an engineering class. Harb *et al.* [6] illustrated the application of the Kolb model and McCarthy's [7] 4MAT system to engineering education. They presented activities that can be used to accomplish specific objectives for each of the four learning quadrants in Kolb's model.

Recently Terry and Harb [8] emphasized the importance of learning style theory as a basis for engineering instruction that will prepare the

* Accepted 30 December 1994.

students to solve real-world problems. In trying to meet employers' concerns about new engineers' inability to define and solve open-ended problems, which the students are surely going to encounter in industry, Terry and Harb [8] suggested activities to be placed in the fourth quadrant of the Kolb cycle. These activities will teach the students how to solve real-world problems. The effectiveness of brainstorming exercises, field trips and student presentations was also discussed, as were design activities in the context of Kolb's learning cycle theory, Bloom's taxonomy of cognitive objectivity and creativity.

Dvorak [9] applied the Kolb theory in developing a teaching technique to cater to the non-traditional students. He examined the challenge facing adult students entering an engineering technology program. He found the non-traditional students to be significantly less abstract than the traditional students. The non-traditional students were more people oriented and often took the lead in classroom participation.

All of these studies recognize the different learning styles of students and demonstrate the enhancement that can be achieved from Kolb's technique.

Other relevant studies and teaching enhancement techniques include those of Stalnaker [10] on three characteristics leading to effective teaching-enthusiasm, concerns for students and sincere desires that the students learn. Klett [11] developed a self-paced method of teaching thermodynamics to a 'slow thermo learner' group of students. The system is self-paced with respect to the opportunity to proceed through the course at an accelerated pace. The students solve a set of self-evaluation exercises and present the solution to the instructor for inspection. Upon satisfactory completion of the exercises, the student takes a pass–fail progress quiz, where a failure will result in a retake or further study and practice exercises. The greatest drawback to this method was motivation and procrastination. The adult students will normally do well with this method. To experience meaningful learning, students need and must be given both motivation-based will and cognition-based skill. Paulsen [12] describes a set of practical examples based on a review of related teaching effectiveness literature. One important strategy is to answer the question: 'Why am I doing this?' Culver [13] discusses ways of stimulating the self-managed learner, which will help the students become effective learners or self-educators. Students can locate the necessary information and are capable of applying the knowledge or skill once it is learned.

On the basis of the experience in my first semester, fall of 1989, teaching the required heat transfer course to technology students, and after a review of teaching enhancement techniques, the present technique was developed. I have also used major elements of this technique to teach a required ME 33 (Thermodynamics and Heat Transfer) to non-ME engineering majors at the Pennsylvania State University at University Park, in the summer of 1992.

It is important to reach all of our students by teaching to each of the different learning styles, and make the students traverse the full learning cycle, thereby making them independent, mature learners and achievers. This paper presents an innovative method of teaching enhancement for teaching any required technical course, and heat transfer in particular, based on the Kolb learning cycle. The innovations include lunch-time tutorials, sincerity index, home work grading by the students and undergraduate research presentations. The technique meets the needs of the diverse group of students normally found in an upper division technology program. An alternative to the Student Rating and Teaching Evaluation (SRTE) for evaluating the students as well as the instructor will also be presented.

THE ENHANCED TEACHING TECHNIQUE

The technique was primarily developed for MET 411 Heat Transfer Course. MET 411 is a one-semester required course for all MET students, with three weekly 50 min lectures. A typical size is 30. However, the teaching technique has been applied to a class of 70 students in ME 23 Introduction to Thermal Science (a required course for non-ME engineering students). It might be difficult to apply the technique to a much bigger size. Most students take the course in their senior year. There is no associated laboratory section. A typical grading policy is as follows:

Homework + Quiz + Project + Class participation	20%
Three tests	20% each
Final (comprehensive)	20%

The grading policy as well as a detailed course outline is presented to the students on the first day of class. The class text is usually *Introduction to Heat Transfer* by Incropera and DeWitt [14]. End-of-chapter problems and practically oriented problems from other textbooks are used as examples and homework assignments.

The enhancement technique is based on the Kolb model as illustrated in Fig. 1. Four types of learners were identified by Kolb. McCarthy combined the learning theory with other learning models to develop the 4MAT learning system. The four questions—why, what, how and what if—represent the internal structure of the learning cycle. Whenever a new topic is introduced, the challenge facing the technology instructor is how to make the students understand and answer those questions. Harb *et al* [6] provide a detailed discussion and application of this model, and illustrate how most learning activities can be intuitively placed in quadrants.

In devising the technique I placed all classroom and learning activities in the quadrants as shown in

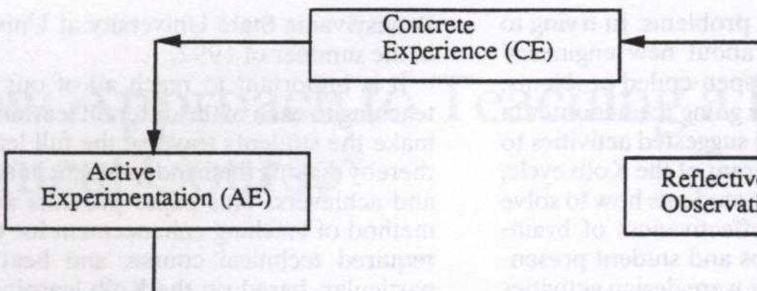

Fig. 1. Kolb learning cycle.

Table 1. These are the activities I feel are important and relevant to the technical course and they differ from the activities in the method of Harb *et al.* [6]. Care was taken not to make the course the traditional professor-dominated lecture. The students are made to cycle through the activities from all quadrants.

The importance of heat transfer across the whole engineering discipline is stressed. Relevance of the course is taught by using everyday occurrences the students can relate to as examples. Motivation is the main objective here. Once the students see how the course affects their life and future goals, they become more motivated. This is normally attempted the first day of class. This activity would fall in the first quadrant as shown in Table 1. One's heating bill in the winter, for example, every North American understands. The need for conservation of energy, better wall insulation, effects of wind on heat transfer coefficient, double-pane windows, insulation rating (thermal resistance) are some examples used in the class. These are terms most of the students are aware of, and some vaguely remember, but very few have ever bothered to learn what they really mean.

A typical lecture period consists of reviewing or summarizing the previous lecture, giving the students an opportunity to clarify any question, doubt or misunderstanding they may have on any concept of the last lecture. I normally introduce a topic or at

Table 1. Elements of the four quadrants.

IV WHAT IF?	I WHY?
Instructor's role: FACILITATOR	Instructor's role: MOTIVATION
open-ended problems	motivation
student presentation	group problem solving
group projects	formal lecture
self discovering	field trip (guest speaker)
what can I make of this/	group projects
share discovering	interactive lecture
evaluate performance	class discussion
field trips (guest lecture)	
III HOW	II WHAT?
Instructor's role: COACH	Instructor's role: EXPERT
homework solved by students on the	formal lecture
blackboard	Textbook reading assignment
homework turned in by the students	visual aids
Field trips	textbook reading assignment
Individual report	problem solving by instructor
Computer simulation or homework	TV demonstration
	library search

most two, and a brief introduction of the topic to be covered next lecture is then given to end the lecture.

The new concept or topic introduced, usually will involve the introduction of a mathematical equation. This is the reflective observation (RO) of the Kolb cycle. In most cases the derivation is omitted, but the use and meaning of the term in the equation are explained. An example problem is solved by the instructor, interactively with the students. The students are prompted to suggest or define the next logical step in the problem solving. The students are thus stimulated and actively involved with the lecture, through thinking about the concepts as well as the application. This satisfies the abstract concept (AC) of the Kolb cycle.

A presentation of an undergraduate research project can lead to discussion of a new topic. The instructor then stimulates the students' thinking by asking questions and engaging the class in discussion of the experimental data and analysis. Undergraduate students can play a very useful and fulfilling role in our research efforts. In a research project [15] they helped to survey the literature, prepare the apparatus and transfer the data from the data logger to a personal computer, where most of the analyses were then performed. The public presentation helps the undergraduate researchers, in that they must spend extra time making sure they thoroughly understand the material. Such a presentation can give them an advantage during the oral defense of their senior year project. The students had a positive opinion of this teaching method.

This activity meets the concrete experimentation (CE) and abstract conceptualization (AC) of the Kolb learning cycle. Students listen and think about the new concept and learn from the presentation by their peers. They thus acquire first-hand experience through observation and practical involvement with the investigation. This is definitely a good way of meeting the CE requirement, for students immediately see the application and limitations of mathematical models. The few moments between the end of the presentation and the question-and-answer period meet the reflective observation (RO) of the Kolb learning cycle for the entire class. This satisfies the entire Kolb cycle.

A video of the boundary layer mechanism the instructor produced from another research project supplements the text by enhancing student understanding of the boundary layer concept and correlation from such experiments. Visual aids are very important when introducing new and complex concepts to the students. Understanding is made easier if they can identify with the author of the video. This video is usually presented during the first class on convection and lasts about 10 min. Research results ranging from determination of thermal conductivity to solar testing have been shared and presented in the past.

A field trip to an industrial plant and a guest lecture are usually scheduled at least once in the semester. Medium- to large-scale industrial plants are located around the campus, so the trips are short. Field trips affords the students an opportunity to relate the concepts and theory learned in class to practice. The speaker selected to deliver the guest lecture this semester, for example, has about 17 technical publications and five US patents, and his responsibility involves project development and implementation of enhanced heat exchanger surfaces for air conditioning and refrigeration. The students are required to write a paper on the main theme of the guest lecture, or in case of a field trip, write a report on the trip. This activity meets the concrete experience of the Kolb learning cycle and fits into the third and fourth quadrants of Table 1.

INTERACTIVE TUTORIAL SESSION

In addition to solving some sample problems in class, a voluntary problem session is organized once a week during lunch break. The atmosphere is cordial and relaxed, and the students are encouraged to bring their lunch. During this tutorial, if there is an assigned or suggested problem a majority of students cannot solve, I would normally solve the problem. In most cases, students volunteer to solve problems on the blackboard. I can call on any student to come to the blackboard to solve a problem. If a student has any difficulty in solving the problem, help is first solicited from the remaining students and finally as a last resort I will lead the student through the problem. The students are thus given the chance to be actively involved and engaged in a supervised application of a new concept, and this fits the concrete experience of Fig. 1. The activity fits quadrants 1 and 4 of Table 1.

By asking the students to explain solved problems, soliciting help from the rest of the class, discussing and exchanging ideas, an alternative method of solution to the problem sometimes arises. Students have different learning styles and ways of looking at problems. The group of activities affords me the opportunity to identify any area of weakness or confusion by the students. This area will then be readdressed in the regular lecture session. In addition to satisfying the CE for the students solving the problem, the method also satisfies the RO for the rest of the students. On the whole this tutorial session meets the objective in all quadrants as well as the four phases of the Kolb cycle. The important aspect of this session is the fact that the students watch their peers at the blackboard and can compare his or her preparation and mastery of the subject to their own.

GRADING POLICY

Approximately five sets of assigned homework problems are collected and graded by the students themselves. My experience is that when homework problems are assigned but not collected and graded, most students do not do them. Yokomoto [16] discusses ways of motivating students to keep up with their homework and stresses the importance of collecting and grading homework. The aim is to convince students that practice is essential for expert performance on tests and quizzes; however, it is important that they understand that homework is not just for the sake of giving them work to do. There must be a balance. The students are encouraged to work in groups or to have study partners. Collaboration and duplication of homework problems are not discouraged or penalized. However, it is stressed that all partners must be sure to understand the problem and its solution, since the quizzes which count for twice as much as the homework, are an individual effort. The homework assignments fulfil the active experimentation (AE) of the Kolb cycle and fit into the third quadrant of Table 1. The students divide themselves into five groups, with usually five students per group. Each group will be given a set of homework problems to grade as a group homework, with a very limited direction and charge from the instructor.

About five in-class 15 min quizzes are given in the semester. The quizzes are graded by the instructor. The quiz is normally one of the assigned homework problems.

Group projects are also given to each of the groups. The objective is to stress the importance of team work and cultivate group spirit. Most of the projects involve open-ended problems, and the students are expected to brainstorm, discuss the various approaches to the problem and finally come to agreement on a solution. A leader of the group then presents the result of findings to the entire class, though any member of the group can be called upon to answer or explain any aspect of the presentation. The project is graded by the instructor, and credit is given for group effort and how well the members of the group were able to work together. This activity again seems to fit all four quadrants of Table 1 and satisfies every phase of the Kolb's learning cycle.

An individual project is also assigned. Involving the use of a computer, a typical assignment might require writing a finite difference code to solve a two-dimensional conduction problem.

PROGRESSIVE CLASS EVALUATION

Well-developed and sincere class evaluation can be a good tool for the engineering instructor to enhance his teaching. Kant [17] summarizes some aspects of increasing effectiveness in teaching based mostly on his general experiences in over two decades of teaching. Both the teacher and the students are evaluated by the students, and a sample of his 'student reaction survey' was also included in his study. I have developed such a survey, different from Kant's but with some similarity. A sample of the class evaluation is shown in Table 2. This evaluation is usually administered three times in the semester. Changes, such as the pace and amount of homework, are usually made when deemed necessary. Concerns are discussed and addressed whenever they are raised.

Figure 2 shows the three evaluations administered by the students during the first semester the teaching enhancement technique was used. Some of the suggestions or shortcomings of the instructor revealed in the survey are then addressed and implemented before the next survey. The overall rating of the instructor increases. The students' rating of themselves were proportional to that of the instructor. Students seem to rate the instructor just as they rate themselves. For example a student rating himself a 6 would likely rate the instructor a 5 or at most a 6. It is very important that the student understand this is not official, and that the university administrators do not use the findings of this survey, nor are they aware of this survey. The bias, injustices and flaws of the SRTE, related to gender, race, religious or ethnic prejudices by the students, was well articulated and presented in an article written by Goldman [18]. Figure 3 is a comparison of the students' rating of both the students and instructor in the first of three surveys done in that semester. The rating of the students as well as that of the instructor also increased in subsequent surveys that semester.

Figure 4 shows a five-semester rating of the overall quality of the instructor in the official SRTE. The score is presented as the difference between the semester's rating minus the lowest rating received by the instructor the first semester before the implementation of this teaching technique. A progressive and steady increase can be seen. A 2.5 point gain was attained in the last semester. The SRTE scale is 1–7, 7 being the highest score.

Figure 5 is based on the so-called sincerity index. On the SRTE, certain items on the evaluation can be absolutely controlled by the instructor, such as questions relating to the instructor keeping his or her office hours or the promptness of returning graded homework, quizzes and tests. If I grade and return all homework, quizzes and test the first time I meet the students after such a test, I expect a score of 7, which is the maximum score possible on any item on the SRTE. The score received on that item becomes the sincerity index. The true score is then defined as the ratio of the raw score on the SRTE to the sincerity index. The score based on the sincerity index is shown in Fig. 5.

The drop rate for the course has steadily reduced, and I have noticed an increase in the passing rate. However, there has not been a significant increase in the number of As: the average grade is about a C+ to B−. The failure rate is an average of one student per semester. So grade inflation appears not to be a consequence.

The class motivation is high, as can be measured by the homework turned in, the presentation of the project by the students and the numbers of students

Table 2. Sample of class evaluation.

SEMESTER EVALUATION AND SURVEY

Name..................
(optional)

Please answer the following questions

1. How are you doing in the this course ? On a scale of 1 to 7, circle a number

1 2 3 Not in it 4 5 satisfactory 6 7 Doing great

2. How is the pace of the class ? On a scale of 1 to 7, circle a number

1 2 3 Slow 4 5 Too fast 6 7 just right

3. How would you describe this class right now (2 or 3 Adjectives)

4. How would you rate the instructor. On a scale of 1 to 7, circle a number

1 2 3 unsatisfactory 4 5 average 6 7 satisfactory

5. What do you think the instructor should do to improve the class ?

6 If you were not doing well, what will you do to improve yourself?

7. Is it (answer in 6) currently available to you ?

8. How relevant and appropriate are the homework problems ?

9. How would you rate the Text book? On a scale of 1 to 7, circle a number

1 2 3 unsatisfactory 4 5 average 6 7 satisfactory

10. Comments: (Tests, grading, grading policy, problem session, ...)

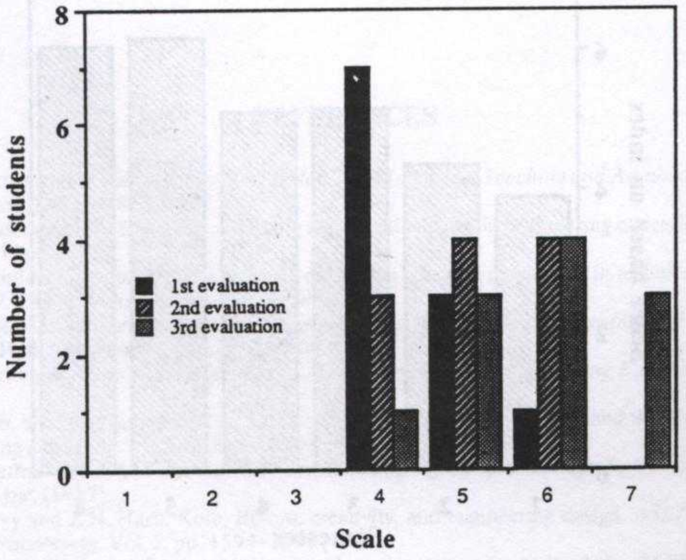

Fig. 2. Class evaluation administered three times in the semester.

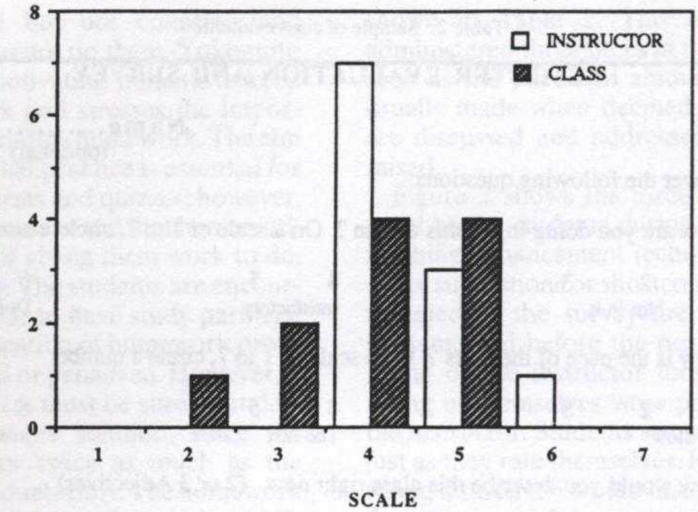

Fig. 3. Relative evaluation of class and instructor by students using Table 2.

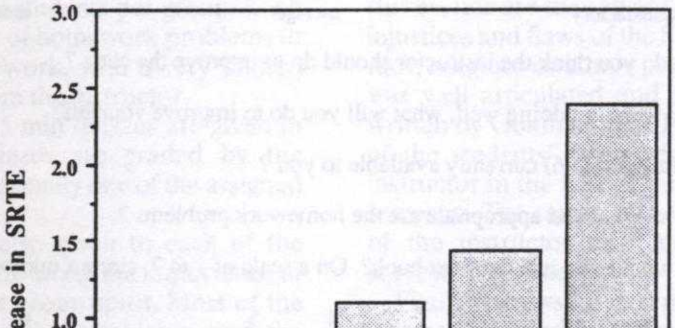

Fig. 4. Difference in SRTE rating after the introduction of the enhancement technique.

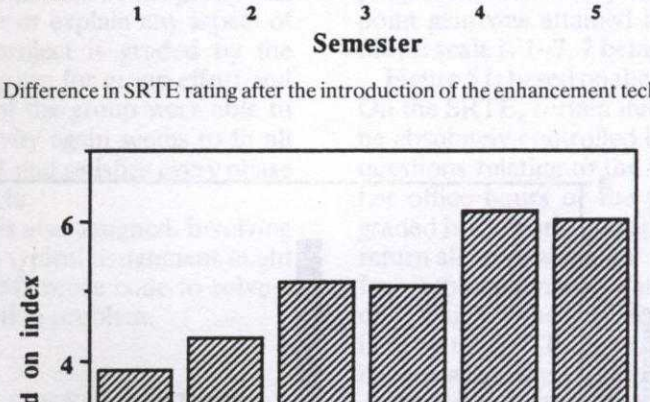

Fig. 5. SRTE evaluation of instructor based on the 'sincerity' index.

volunteering to solve problems in class during the tutorial. As the semester progresses, the number of students attending the voluntary tutorial session increases. Most of the homework problems are turned in. The students do a good and quick job of grading the homework. And because their peers grade the homework, the students do a more thorough job on the homework, the student grader feels better being a part of the grade-awarding team for the course. Every student and group is given a chance to grade.

The group concept has been very helpful to the students. I have discovered that the non-traditional student always volunteers to lead the group and generally does a better presentation of the solution. The non-traditional students have been a good resource for the class, especially in integrating the lecture with real-world experiences. They know all too well the strength in group work and solving open-ended problems.

The drawback in the technique has been the reduction in the number of topics covered in the semester. Textbook selection for technology courses has been difficult. Most texts are geared towards engineering students and lack the much needed practical-oriented end-of-chapter questions needed for technology students. The instructor has to devote much time to teaching the class, thereby taking away time needed for 'research', which in some technology programs is not very well defined [19]. This is a problem only for faculty in institutions which require research. Some students also feel that though the tutorial is optional, by attending the tutorial session, the course amounts to a four-credit course instead of the official three-credit course. No new material is ever covered in the tutorial session so there is no loss of continuity for those students not attending the session.

I have been very pleased with the method, and the comments of the students at the end of the course as written on the SRTE has been very encouraging. Some of the comments are attached in the appendix.

CONCLUSION

An innovative and effective teaching enhancement technique has been presented. The innovation include lunch-time tutorials, sincerity index, homework grading by the students and undergraduate research presentations. The technique meets the needs of the diverse groups of students normally found in an upper division technology program.

The technique has been shown to enhance teaching as shown by the rating of the students by the students. The drop rate was also seen to decline. There was also a significant rise in the SRTE score of the instructor, both in the overall quality of the instructor as well as the overall quality of the dress. The motivation level of the students was high, as reflected in the number of students attending the voluntary tutorial session and their final grade in the course.

The drawback of the system is that the amount of material covered in the course has been reduced. However, I would rather cover fewer topics in this way than lecture to graduate students who just went through the motions. Becoming a good and effective teacher is not a supernatural gift. With dedication and effort, one can continue to modify one's technique and take risks at trying new methods until 'perfection' is attained.

Students who learn collaboratively retain much more than students who serve as empty vessel into which a lecture is poured.

Acknowledgements—The assistance and suggestion of Dr Bob Ness, Associate Professor and Head of the Department of English, Dickinson College, Carlisle, PA, and Dr Bill Welsh, Associate Professor of Engineering, PSU Harrisburg is greatly appreciated. I would also like to thank Dr Gautham Ray, Director of the School of Science Engineering and Technology, PSU Harrisburg, for his financial support.

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APPENDIX

These are some sample comments from the MET 411 Heat Transfer class at PSU-H (technology students) and Introduction to ME 23 Thermal Science course at PSU University Park (engineering students).

MET 411

'Interesting topics. Good examples. Problem sessions were helpful', 'Get rid of the irrelevant computer program', 'Extra problem class was very helpful', 'The instructor is concerned if students are getting the most out of the course', 'I find that having a few hw worked out very helpful', 'Course is very demanding', 'Tutorials created a four credit class'.

ME 23

'Too much material', 'Course material seem very applicable', 'Book was good', 'Instructor had a willingness to teach', 'Highly recommend having him teach here', 'I actually enjoyed the course . . . Can you believe it???'

Harris Imadojemu, an assistant professor of engineering at Penn State University at Harrisburg since 1989, received his MSME from North Carolina A&T State University, Greensboro and his Ph.D. degree in mechanical engineering from North Carolina State University, Raleigh in 1989. He teaches various courses in the thermal sciences area at both the undergraduate and graduate level. His research areas currently include boiling and condensation, enhanced heat transfer application and energy generation and conservation. He is a member of ASEE, SAE, ASME, and chair of the local heat transfer chapter of the ASME.