ChE classroom

FLUID MECHANICS CAN BE FUN*

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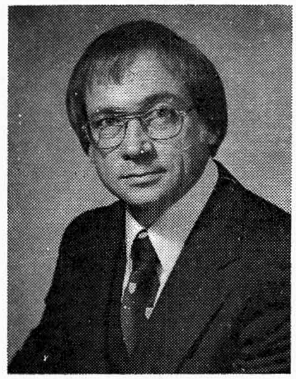

Robert F. Blanks: I have had approximately equal periods of experience in chemical engineering education and in industry. After obtaining my PhD in ChE at the University of California, Berkeley, I joined Union Carbide's Plastics Process R&D section in Bound Brook, New Jersey. After seven years there, having moved up the ranks with one foot on each side of the dual technical-administrative ladder, and on the verge of moving into the administrative line, an old latent urge motivated me to leave Union Carbide and join the ChE Department at Michigan State University. I taught there for nine years and was promoted to the position of Professor in 1978. During my academic tenure, I consulted with Dow, Corning Glass, and Amoco Chemicals. Although I enjoyed my classroom teaching experience, my consulting work was more rewarding. Driven by salary differential, large classes, and turned off by the grantsmanship game, I returned to industry where I am now employed as a Senior Research Engineer by Amoco Chemicals R&D in Naperville, Illinois.

IN MY FIRST FEW YEARS of teaching engineering at the university level, I used the traditional lecture method. Homework assignments were collected and routinely graded. Course grades were assigned based upon a composite score of homework grades, grades on hour examinations, and a final examination grade. A class grade distribution was obtained from a statistical t-score analysis. Student response to this approach was generally favorable but not exciting. Several events combined to motivate me to examine alternative teaching methods.

An article in the student newspaper caught my attention and plagued my conscious thoughts. In effect, the article showed photographs of sleeping or bored students in several classrooms and posed the question, "Are these people enjoying this educational experience?". I began looking in classrooms and at my own classes with this question in my mind. For the most part, I concluded that the answer was "probably not."

At this point, I engaged in a continuing series of lengthy discussions with a woman, who is now my wife, Judy, about alternatives offered by the field of humanistic education. Judy and I attended several personal growth workshops led by Dr. Sid Simon and a values clarification workshop led by Dr. Howard Glasser-Kirschenbaum. I began reading a great deal in this area, including a book by Robert C. Hawley and Isabel L. Hawley [1]. The title of the Hawleys' book is *Human Values in the Classroom*. I began to try some of the strategies and methods I was learning in my classroom. In the fall of 1976, the experience and response in my junior class of fluid mechanics was so rewarding that I decided to share it with others by writing this paper for a session at the fall, 1977, AIChE meeting. The session title is "Caring in the Classroom."

HYPOTHESES

BASED UPON THE experiences motivating me to consider alternatives to the lecture method, I offer the following hypotheses or rationale for the methodology used in the course about to be discussed. Much of this thinking comes from the Hawleys' book [1], for which I am gratefully indebted.

It is difficult for a teacher to educate students by talking *at* them, or by lecturing, in the manner of a preacher or a wise parent. Students often learn most by experiencing, by problem solving, by creating and observing the need for knowledge

*Presented at the November, 1977 AIChE Meeting, New York Session, "Caring in the Classroom".

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and then by seeking out the knowledge from several available sources, e.g., peers, teaching assistants, books, the professor. Role playing the part of an industrial engineer on an assignment, laboratory demonstrations, intriguing problems, and analogies can combine to make the process of learning effective and enjoyable to the student.

An authoritarian, judgemental attitude on the part of the teacher can stifle creative thinking by the students. Empathetic listening by the teacher, in the classroom or on a one-to-one basis in recitations and during office hours, may create a rapport between teacher and students and among students, which often increases academic achievement. This community building can become an important aspect of planning a class. Positive reinforcement and positive feedback—from students to teacher, from teacher to students, and among students—tends to check boredom, to provide self-confidence, and to generate enthusiasm on all sides.

In planning for the teaching of any given course, it would be well for the instructor to consider elements related to the process of learning as well as those concerned with the chronological sequence of content. Areas such as community building, achievement motivation, providing for student-teacher and student-student communication, and the physical set-up of the classroom may be important concerns. Often the rigid physical arrangement of rows of desks facing a lecture stand is a limitation to open student-teacher interaction in a sharing sense. One of the teacher's first tasks is to communicate to the students the goals of the class as the teacher sees them. It is often helpful at this point to attempt to involve the students in setting goals for the class.

One concept which is often difficult for me to remember is that a group of students in a class do not function collectively in the sense of their grasp of material or response to particular teaching methods. On the contrary, a class is composed of a number of individuals with varying abilities, with unique sets of external demands upon them, who respond separately to different methods of teaching such as the lecture, group work, independent study, problem solving situations, etc. Therefore, if a variety of learning situations can be created in a classroom, or outside of the classroom, each student may seek the method in which he or she is most comfortable and most likely to learn.

A teacher may possess a great deal of knowledge in a field and it is often most efficient to pass this knowledge on to a class by means of lecturing. However, in addition, it is important for the teacher to help the student learn how to approach problems, to develop solutions and assess the accuracy of results, to become creative thinkers, and to seek alternate sources of information. A teacher might better view himself or herself as a facilitator of learning rather than as a dispenser of information.

In the traditional lecture system, many students attempt to place the responsibility for their learning on the teacher. This responsibility belongs to the student. Self-motivation is one key to high achievement. This is a more obtainable goal when the students have played a role in establishing course objectives, have a variety of alternative learning processes available, have a good rapport with the teacher and with each other, and have even helped to establish criteria for measuring achievement. It seems very desirable to attempt to create a situation where students and teachers alike work together to help everyone achieve to the maximum of their abilities rather than an adversary situation where students attempt to outwit the teacher, or to beat each other at the grading game. The negative aspects of grading are discussed in the Hawleys' book [1] and elsewhere [2, 3]. I will not attempt to thoroughly discuss this controversial subject here. It appears to me that there is a real conflict between the negative aspects of grading, the need for honest evaluation of achievement, and the desire for company recruiters to have the students of engineering rank ordered.

METHODOLOGY

IN THE FALL OF 1976, I attempted to incorporate some features of the humanistic education approach into teaching fluid mechanics and heat transfer to a group of 87 junior ChE students at Michigan State University. The course was divided into two sections of 48 and 39 students, respectively. Each section met for five hours per week, 3 one-hour periods and 1 two-hour period. Two senior ChE students and one graduate student met with me and the class in the classroom.

Role playing the part of an . . . engineer on an assignment, laboratory demonstrations, intriguing problems, and analogies can combine to make the process of learning effective and enjoyable . . .

TABLE 1

Class Outline

Text: Bennett and Myers, "Momentum, Heat, and Mass Transfer," 2nd edition, McGraw-Hill Book Co. (1974).

TOPICS

Introduction
Fluid Behavior
Overall Mass and Energy Balances
Overall Momentum Balance
Flow Measurement
Boundary Layer and Turbulent Flow
Dimensional Analysis and
Design Equations for Fluid Flow
Heat Transfer by Conduction
Convective Heat Transfer Coefficients
Heat Transfer with Laminar Flow
Heat Transfer with Turbulent Flow
Design Eq. for Convective Heat Transfer

The course was divided into 9 topic areas with assigned problems and a one-hour examination for each area. There was a two-hour final examination at the end of the term.

The course outline is shown in Table 1. Each week began with a one-hour lecture introducing the important concepts for the week. The following three class hours for the week were devoted to problem solving sessions. Students worked together on the assigned problems in groups of two or three, or some students chose to work individually. As the Hawleys pointed out, practice in collaborative information processing can be a valuable part of the learning experience. In industrial and governmental research and engineering, teams of people develop information for use by management in decision making. Problems which sometimes seem overwhelming to an individual may be comprehensible to a group. Students working in group problem solving sessions obtain training in shared information processing and can become aware of a need for interdependence in achieving their own goals. They may develop a sense of what to expect from different types of people and learn something about the difference between unwisely trusting incompetent sources and being unwisely suspicious of helpful, competent sources [4]. They also spent some time at home with the assignment.

The student assistants and I circulated throughout the classroom during the problem solving sessions and talked to the individual student groups as the need arose. Occasionally, I would give a short "mini-lecture" on common problem areas. The hour examination at the end of the week was structured in such a way that mastery of the concepts required to solve the assigned problems usually meant that a student could do quite well on the examination. The student's solutions to the assigned problems were not picked-up or graded, yet almost all of the students attended the problem solving sessions and attempted to work the problems. Some students attended the sessions in both sections. Some students asked for, and were given, additional problems for exercise. For two of the nine weeks, the student's problem solutions were accepted in lieu of the hour exam although an examination was also available for those that chose that alternative.

A movie on turbulence and several demonstrations in the fluid mechanics laboratory helped the students visualize the application of theory. The orientation of the course was problem solving and students were helped to role-play engineering assignments. For example, copies of the final examination questions, some from the Bennett and Myers textbook [5] are shown in the Appendix.

TABLE 2

Feedforward Form

1. How would you like to see this class run and what would you like your part to be in helping it to function in this manner?
2. What do you expect from the class leader?
3. What do you expect from yourself?
4. What special concerns, issues, or questions would you like to have considered as part of an input to this course?
5. Open comment:

EXPERIENCES AND RESPONSES

By the end of the term, I had become acquainted with all of the students on a first-name basis. This was facilitated by holding a large number of office hours and on some weeks specifically requesting that the students stop in during some portion of the office hours. I feel that an open and caring atmosphere developed within the class. On the first day of the class, the students completed a feedforward form telling about their expectations for the course, the professor, and themselves in the course. The form is shown in Table 2. Frequent feedback forms were used as the course progressed and helped to promote the openness. Complete responses to the feedback forms were

It is difficult . . . to educate students by talking at them, or by lecturing, in the manner of a preacher or a wise parent. Students often learn most by experiencing, by problem solving, by creating and observing the need for knowledge.

distributed to the students the period after they were handed in. Examples of two feedback forms are shown in Table 3 with student responses included.

The use of feedforward forms helps the students to feel that they have a role to play in setting the goals for the course. Students pause to think seriously about their expectations and goals for themselves. The feedback form helps to show a willingness to change direction and that the teacher is concerned with students feelings. Students also communicate their feelings to each other. The usefulness of feedback is discussed by the Hawleys [6]. Students may feel rather powerless over their lack of opportunity to influence the course of their educational experience. Feedback forms provide a way for the teacher to address this need. Positive feedback from the class may motivate the teacher to try even harder to give the students a valuable and meaningful experience in the classroom. Problem areas may be uncovered which can be corrected before they become serious.

Responses by the students regarding the class were overwhelmingly positive. Performance by the students on examinations was better than any previous time when I taught this subject. Most of the students commented that they felt they had really learned something in this course and a few of their comments are listed in Table 3. I felt that this was the best and most enjoyable course that I have ever taught.

TABLE 3
Feedback Forms and Responses

Responses in *italics*
On a scale of 1 to 7 with 7 being high

		7	6	5	4	3	2
The class rated	—	*19*	*41*	*20*	*6*	*1*	*0*
The lecture rated	—	*19*	*35*	*27*	*7*	*3*	*1*
The recitation rated	—	*27*	*28*	*21*	*9*	*0*	*2*
Teaching assistants rated	—	*15*	*25*	*24*	*7*	*2*	*0*
The professor rated	—	*33*	*42*	*9*	*1*	*1*	*1*

On a continuum scale from strongly disagree to strongly agree please respond to the following:

	Majority Opinions
CHE 305 requires too much time outside of class hours	*neutral*
Having 9 tests per term is better than having 4 tests per term	*strongly agree*
I feel like I'm learning some fluid mechanics	*strongly agree*

And I'd also like to say:

- *I like the approach—noncompetitiveness.*
- *I think the way the class is being conducted is great.*
- *I enjoy the course and understand the material much more than I would under standard classroom procedure.*
- *I like it when the professor remains flexible throughout the term.*
- *Best class I have ever had.*

CONCLUSIONS

LARGE CLASSES MAY BE taught sensitively with a significant amount of professor-student interpersonal relationship developing. The lecture mode of teaching may be successfully minimized in a difficult and demanding technical course. Group and individual problem solving sessions, with professor and teaching assistant involvement, are effective methods for learning. Frequent examinations are an effective motivation to learning and tend to ease the pressure of exam taking.

Student feedforward and feedback forms give the students a good feeling of being involved in a course and give the professor a good feeling about his/her teaching experience. An open, caring attitude on the part of the professor promotes a like response from students and a significant amount of 1:1 professor-student contact outside of the classroom. Students may be effectively motivated to learn subject material without collecting and grading homework. An open, humanistic approach to teaching engineering can result in improved student learning, self-confidence, and self-appreciation. □

ACKNOWLEDGMENTS

I would like to validate all of the people who have helped me through some significant personal growth stages in my life and who have helped me to become aware of the concept of caring in the classroom. In particular, I want to validate my wife, Judy, Sid Simon, Carrie Owens, and Carol Weiskopf. I thank the Hawleys for such a lucid presentation of valuable ideas in their book. I also appreciate the work of the teaching assistants in the class; Mike Goodnight, Barb Dittmann, and Terry Haske. Our department secretary, Ann Brown, typed all of the feedback responses

weekly without complaining and that was a significant task. Last, but not least, I appreciate the great class of students enrolled in CHE 305 last fall.

REFERENCES

1. Hawley, Robert C., and Isabel L. Hawley, Human Values in the Classroom, Hart Publishing Co., New York (1975).
2. Kirschenbaum, Howard, Sidney B. Simon, and Rodney W. Napier, Wad-ja-Get? The Grading Game in American Education, Hart Publishing Co., New York (1969).
3. Glasser, William, Schools Without Failure, Harper and Row, New York (1969).
4. Reference 1, page 136.
5. Bennett, C. O., and J. E. Myers, Momentum, Heat and Mass Transfer, McGraw-Hill, New York (1974).
6. Reference 1, pages 94 and 95.

APPENDIX
Final Examination Questions

SECTION 1

1. **Water is retained in a mountain lake whose surface is 280 ft above the inlet to the turbines in a powerhouse. Surveyors have laid out the best line location for the piping system to bring water from the lake down to the power house. The route is 3100 feet long.**
   You are the engineer working for the community's power generating company. What is the minimum standard diameter of pipe which may be used in the line so that the natural flow will be 1000 gallons per minute and the pressure at the turbine inlet will be 100 psig? Assume turbulent flow.
   After obtaining a solution, justify the neglect of any terms in the equation required to obtain the solution and justify any assumptions made about the type of flow.

2. **You are an engineer in the process development section of a polymer manufacturing company. Specify the horsepower required and the pressure which a pump must develop for the following application. Pump 5000 lb/hr of a high viscosity, Newtonian, fluid 75 feet through a 2-inch diameter transfer line. The material is being transferred from one chemical reactor at 900 mm Hg absolute pressure to another reactor at 450 mm Hg absolute pressure. The material has a viscosity of 50,000 cps and a specific gravity of 0.95. Place the pump at the exit of the first reactor. Assume that the efficiency of the pump is 75%.**

3. **You are the design engineer in a petroleum refinery. Oil is being cooled in the inner pipe of a double-pipe heat exchanger. The oil flows at a rate of 27,500 lbs/hr and is cooled from 100°F to 89°F. The inside tube is a 3/4″ 16BWG steel tube. The oil is cooled by water flowing counter-currently at a flow rate of 8000 lbs/hr. The water enters the exchanger at 68°F. The outer tube is 3″ sch 40 iron pipe. Calculate the required heat exchanger length. Oil properties are:**

T°F	75	80	85	90	95	100
μ(cps)	3.9	3.7	3.5	3.3	3.1	2.9

C_p = 0.474 Btu/lb°F
κ = .0789 Btu/ft^{2}hr °F/ft
ρ = 51.5 lb/ft^3

4. **You are a production supervisor in a food processing plant. Orange juice is being concentrated by evaporation of moisture from a film of juice flowing down the inside wall of a large pyrex tube. The tube is heated on the outside by steam at 220°F. The orange juice flavor is easily affected by overheating; therefore, no portion of the juice can have a temperature exceeding 160°F for even a short period of time. Find the limiting bulk velocity for the case where the bulk mixing-cup, temperature of the orange juice is 140°F, and the maximum O. J. temperature is 160°F.**
   DATA: Convective coefficient for steam: h = 1000 Btu/hr ft^2°F
   Convective coefficient for the orange juice: h = 150 $u_b^{1/2}$ where u_b is bulk velocity of the film in ft/sec and h is units of Btu/hr ft^2°F (i.e., conversion factors are built into the 150)
   Thermal conductivity of pyrex = 0.5 Btu/hr ft°F
   Pyrex wall thickness 1/4 inch

SECTION 2

1. **You are a design engineer in a petrochemical plant. Calculate the horsepower required and the pressure which a pump must develop for the following application. It is necessary to pump benzene at 70°F from a storage tank at atmospheric pressure to a pressure vessel at 50 psig through the piping arrangement described below. The flow rate is to be 320 gallons per minute. Assume the pump to be used has an efficiency of 80 percent.**
   Piping System: Ordinary entrance, 10 feet of horizontal 4″ sch 40 pipe, pump, open gate valve, 80 feet of 3″ sch 40 pipe plus 2 elbow and an open check valve, into the pressure vessel. The level in the pressure vessel is 20 feet above the level in the storage tank. Assume that the benzene enters the pressure vessel below the level of liquid in the vessel.
   Assume benzene density is 54 lbs/ft^3.

2. **You are a project engineer for a pipe-line company. A 20-mile-long pipeline delivers petroleum at a rate of 5000 barrels per day. The resulting pressure drop is 500 psi. If a parallel line of the same size is laid along the last 11 miles of the line, what will be the new capacity of this network? Flow in both cases is laminar and the overall pressure drop remains 500 psi.**

3. **You are a process development engineer for a synthetic plastics company. A process requires the development of a heat transfer device. A fluid is to be heated in a double-pipe heat exchanger. The fluid is flowing inside a 1-inch sch 40 steel pipe with a velocity of 1 ft/sec. The fluid is to be heated in the pipe from 100°F to 160°F. The annular space between the pipes contains steam condensing at 200°F. The heat-transfer coefficient for condensing steam is 2000 Btu/hr ft^2°F. The fluid has the following**

average physical properties:

density	— 56 lbs/ft^3
specific heat	— 0.47 Btu/lb°F
thermal conductivity	— 0.07 Btu/hr ft°F
viscosity	— 4.0 cps

Find the length of pipe required for the exchanger.

4. You are a tired and puzzled student in ChE 305 (the real you?). The professor puts the following crazy question on the final exam. (Don't panic this is a relatively easy problem, just read carefully.)
The circulation of blood in the finger maintains a temperature of 98.6°F at a short distance, say 1/8 inch, below the surface of the skin. The nerve endings, which are temperature indicators, are 1/16 inch below the surface of the skin, your distress is considered to be noticeable when the nerve endings attain a temperature of 110°F. Using these criteria, find the maximum temperature of water in which you could hold your finger. Assume the system is adequately modeled as a flat plate.

Thermal conductivity of flesh and blood	— 0.35 Btu/hr ft°F
Convective coefficient for finger dipped in water	— 100 Btu/hr ft^2°F

1 ft^3 contains 7.48 gallons
1 H.P. = 550 ft-lb$_f$/sec
1 bbl = 42 gallons

ChE books received

"Advances in Cryogenic Engineering" Vol 3. Edited by K. D. Timmerhaus, Plenum Press, New York. pp 747, 1978. $49.50

This is the proceedings of the 1977 Cryogenic Engineering Conference held at the University of Colorado, Boulder, CO. Papers include superconductivity applications, heat transfer, mass transfer, cryogenic techniques and applications, and LNG design and properties.

"Applied Cost Engineering" by F. D. Clark and A. B. Lorenzoni. Marcel Dekker, Inc., New York. pp 297, 1978. $24.50

This is the first in a series of reference books and textbooks on cost engineering. It is concerned with cost estimation and cost control and does not discuss engineering economics, the third area of cost engineering. The authors include few specific data but give the reader basic philosophy and ideas for developing his own data, estimating method or cost control system.

"A Programmed Review of Engineering Fundamentals" by A. J. Baldwin and K. M. Hess. Van Nostrand Reinhold, New York. pp 287, 1978. $18.95

This programmed text is for anyone preparing for the National Engineering Fundamentals Examination. The text includes review material in mathematics and science and engineering fundamentals.

Continued on page 52

ChE letters

CITATIONS CORRECTION

Dear Sir:

In the Fall issue of *CEE* Professors Carbonell and Whitaker identified the origin of the method of volume averaging as a pair of independent papers by Slattery (1967) and Whitaker (1967). That citation unfortunately overlooked the work of Anderson and Jackson (1967) who also derived the spatial averaging theorem independently and used the result to analyze motion in a fluidized bed.

Anderson, T. B. and R. Jackson, "A Fluid Mechanical Description of Fluidized Beds", I.E.C. Fund *6*, 527 (1967)

Slattery, J. C., "Flow of Viscoelastic Fluids Through Porous Media", AIChE *13*, 1066 (1967)

Whitaker, S., "Diffusion and Dispersion in Porous Media," AIChE Journal *13*, 420 (1967)

Stephen Whitaker
Visiting Professor
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CONFERENCE ON CASE STUDIES

Editor:
Please publish the following announcement:

"National Conference on Case Studies in Engineering Education" sponsored by the ASEE Engineering Case Committee, March 28-30, 1979, Columbia, South Carolina. Topics: Preparation, writing, and use of case studies; application of cases to instruction in specific engineering disciplines; case use in legal, political, ethical, and economic aspects of engineering. Papers dealing with these topics will be published in a Proceedings which will be available at the conference. For information, contact the Office of Continuing Engineering Education, University of South Carolina, Columbia, South Carolina 29208; telephone 803-777-6693

Tim A. Jur
Conference Chairman

CALL FOR PAPERS

Dear Sirs:

The Irish Branch of the Institution of Chemical Engineers is organizing an International Conference on Solids Separation Processes to be held in Dublin in April 1980 in association with the Annual General Meeting of the Institution.

The Conference Organizing Committee is inviting papers for the conference and would be pleased if you could give some prominence to the "Call for Papers" in your journal.

Abstracts should be sent, as soon as possible, but not later than April 1, 1979, to

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