Teaching Undergraduate Thermodynamics...

USE OF SLIDES AND SELF-STUDY EXAMPLES

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BEFORE LAUNCHING INTO a description of the methods that I utilize in my teaching, I feel that definitions of the following terms are required:

> **LEARNING may be conceived of as a change, due to experience, in the students ways of thinking, feeling, and acting. The effectiveness of the learning process may be thought of in terms of (1) the magnitude of the changes taking place in the individual student or (2) the proportion of students who have changed significantly in one or more characteristics relevant to the learning process. Thus conceived, education may be regarded as a system of learning experiences which brings about certain desirable changes in students. [1]**
> **MOTIVATION, in the scientific sense, may be defined as the measure of the direction and intensity of the expenditure of animal energy. . . . Human institutions may be said to be formed primarily to motivate men. . . . Educational systems are designed to motivate human beings to accept a cultural heritage. [2]**

The objective of my teaching can now be introduced—I seek ways of maximizing the learning of a given subject matter by providing conditions which are motivational for my students. To be more specific, this paper will discuss methods used in teaching thermodynamics to students at the University of Pittsburgh. The details of this approach have been described elsewhere [3,4] and accordingly only the salient features will be introduced here.

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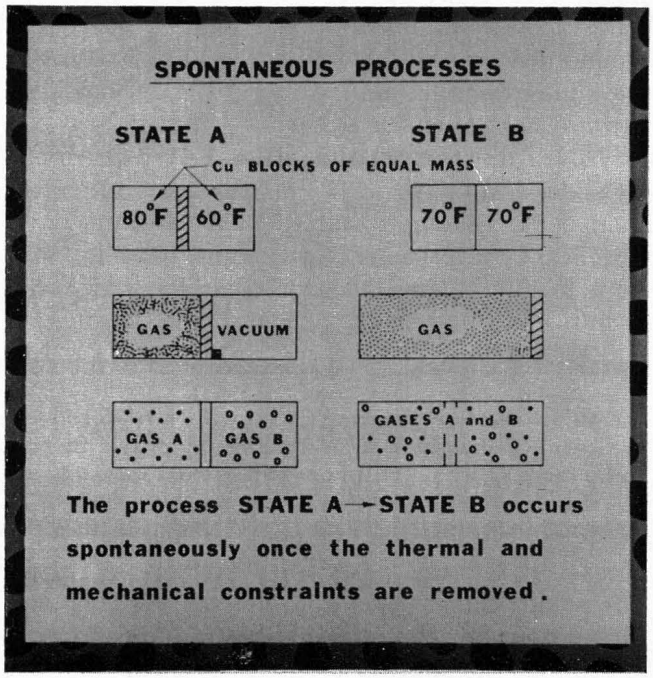

FIGURE 1.

Three hundred and thirty nine 35 mm slides were developed. The slides were prepared by using pressure sensitive black letters and symbols (Tactype) on white cards. These cards include the necessary definitions, postulates, laws, equations and a limited number of applications of the subject matter. These individual cards were then superimposed on colorful backgrounds and colored slides were prepared from this combination. The backgrounds include pop-art posters, colorful wrapping papers and examples of contemporary modern art. Figs. 1 and 2 present black and white versions of two of the slides used in the thermo-

dynamics course.

Each of the cards used to prepare slides was photographed and made into an Active-Involvement book [5] for classroom use. Additional space is provided on each page in this book for student note taking. In use, the student can add relevant material introduced by the lecturer directly in his or her Active-Involvement book as the slides are being shown. It has been my experience that I communicate more information that serves to tie the slides together and elaborate their meaning with my continued use of them.

Now I must admit that when I first developed my slides and their companion, the Active-Involvement book, I thought that I would see immediate, significant improvement in the ability of my students to do problems in thermodynamics. After all, hadn't these materials provided the motivation necessary to greatly enhance student learning? For some students the answer was yes, but, unfortunately, for most the answer was no. I began to see that the slides presented the theory but the students needed additional help in applying the theory to solve problems. If I wanted the students to demonstrate problem-solving skills I had to provide them with lots of practice of those skills and/or lots of examples of solved problems. The book by Abbott and Van Ness [6] in Schaum's Outline series was not available so I elected to prepare materials of my own. I generated a series of *self study examples* that serve as a major input for student learning outside the classroom. These *self study examples* now number in excess of 100, with examples both in the "British" system and SI system of units. The *examples* are of two types:

1. **Those having a problem statement followed by a listing of the educational objectives which are appropriate for the solution of the problem followed by a detailed solution to the problem;**
2. **Ones similar to those described above but which leave some of the steps of the solution up to the individual student to complete.**

The later category is necessary. Without it, too many students just sit back and do not "dig" hard enough with those *self study examples* that are solved completely. It is not enough for them to recognize that I know how to solve thermodynamics problems; they must recognize that they have to learn how to solve them also. Before turning to a discussion of my recent experiences concerning my materials, I feel it appropriate to spend time discussing educational objectives as I feel they are an important element in *self study examples*. Mager [7] was an early advocate of the use of instructional (educational) objectives. According to Mager, a properly written instructional objective must:

1. **Describe what the learner will be doing when demonstrating that he has satisfied the objective;**
2. **Describe the important conditions under which the learner will demonstrate his competence;**
3. **Indicate how the learner will be evaluated, or what constitutes acceptable performance.**

The book by Mager [7] and a paper by Stice [8] provide a good discussion on the preparation of instructional objectives. Two aspects concerning the use of instructional objectives discussed in Stice's paper deserve our attention. First, several objections to the use of instructional objectives are raised and shown to be without merit. Second, Stice comments on the fact that others are too rigid in their choice of words used to write acceptable objectives. In particular, Walbesser et al [9] suggests that only the following nine action verbs are to be employed: to name, identify, describe, construct, distinguish, demonstrate, order, state a rule, and apply a rule. Stice suggests that words like "derive", "explain", "calculate", and "estimate" are sufficiently unambiguous to be added to the above set. I, too, find these words convenient and well understood when used to prepare objectives for students. Certainly just which words can be considered to be acceptable will depend upon the subject matter of concern.

Objectives 1, 2, and 3 shown below are specific examples of educational objectives used in my course.

Example 1.

The student must be able to utilize the relationship

$$h \equiv u + pv$$

to convert the specific internal energy into the specific enthalpy and vice-versa.

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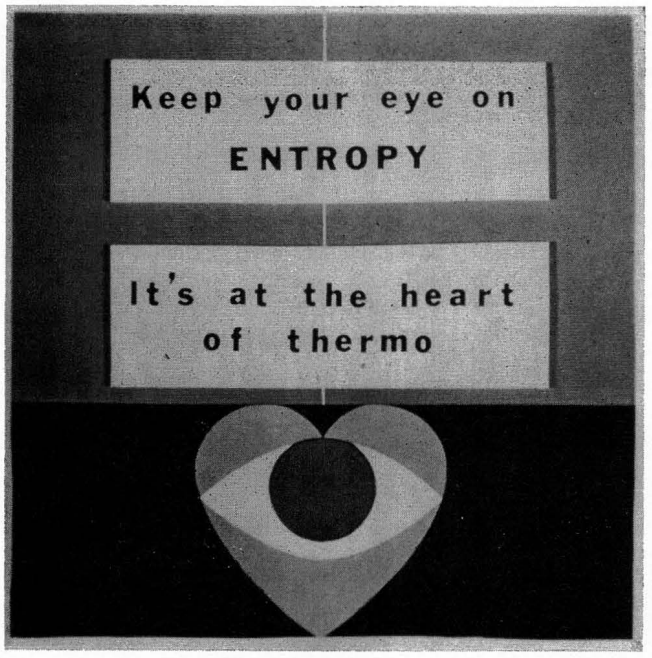

FIGURE 2.

Example 2.
The student must utilize the fact that two independent intensive properties are sufficient to set the intensive state of a simple comprehensive fluid.

Example 3.
Given a table of thermodynamic properties of a fluid, a steam table for example, the student must be able to correctly locate a given equilibrium state once the conditions described in Example 2 have been met.

I am convinced of the merit of using educational objectives and encourage you to prepare them for your students. I have found, however, that students are largely unfamiliar with them and some class time must be devoted to explaining their importance and their use.

Now we get to the "bottom line"—do my materials work? I think they do and I base this judgement on two sources of information:

- **My own experiences in testing students with and without the materials.**
- **Student reactions described in course evaluations.**

While both of these sources are subjective, I feel that they do provide evidence of an enhanced learning experience for my students. Students do demonstrate considerably more organization in the solution of thermodynamics problems. Their approach is more direct and largely avoids many of the errors in applying the basic principles of the subject matter. I feel that the *self study examples* are largely responsible for this.

What are the students' reactions? The following is a summary of student response gathered from an anonymous survey taken near the end of the course.

The instructor was considered an interesting and dedicated teacher who cared about his students. The course was well structured and the instructor used new teaching techniques successfully. The work book (Active-Involvement book) was excellent.

The following represents individual student comments.

I came into this course with apprehension. I was told that thermo was the hardest and dullest course of all the engineering courses I was ever to take. However, Dr. Brainard has made this the most intersting as well as informative course I have ever taken. His zeal for the subject is extremely apparent and he communicates this well to the class.

It is encouraging to see someone take as much time in preparing a course as Dr. Brainard has.

Dr. Brainard is unbelievably dedicated and concerned about the student. His self study examples **are very helpful.**

I feel these comments speak for themselves.

Will my material work as successfully for others? I don't know. I have found that faculty tend to develop an inertial effect in their teaching methods. (I am no doubt guilty of this also.) Certainly individual faculty members will and should develop their own style and that style must be one that they believe in and are comfortable with. □

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