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Abstract

An instructional model has been previously described which provides a comprehensive approach to classroom teaching.[1-3] At its core this model consists of a structured format for preparation and presentation of lecture material, and techniques for engaging students in the classroom and developing interpersonal rapport with them. This paper presents the author's experience implementing this model in a large research university. In addition to describing modifications required in this setting, a comparison of teaching evaluations for the same course before and after implementation will be presented. A t-test was conducted for each of 27 evaluation questions to determine which were affected by the change in teaching style. Improvements could be divided into three general categories: communication of course goals and objectives; questions associated with the students' feelings about the course and the instructor; and questions relating to the course content.

1. Introduction

The classic Seymour and Hewitt study indicates attrition from science, math, and engineering programs is strongly affected by poor teaching practices.[4] Fortunately, a number of books and training workshops are available that provide concrete, definitive techniques for improving classroom instruction. This paper focuses on one such workshop, based on the instructional activities within the Department of Civil and Mechanical Engineering at the United States Military Academy. This workshop has been described previously, and is referred to in the literature as T^4E (Teaching Teachers to Teach Engineering).[1-3] The workshop itself is currently known as the ExCEEd Teaching Workshop, under sponsorship of the American Society of Civil Engineers.[5] To be consistent with previous literature, this paper will refer to both the workshop and the model as T^4E. The key elements of the T^4E model are: communicating expectations, structured content, engaging presentation, and interpersonal rapport. Each of these areas will be discussed further below.

Several papers have described assessment of T^4E from the viewpoint of the content and conduct of the workshop itself.[3,6,7] Both numerical ratings and written comments consistently show that the workshop is considered valuable. Participant self-assessments before and immediately after the workshop indicate that the participants felt that the workshop is helpful in improving their teaching.

Less information is available on the extent to which the workshop actually improves teaching in the classroom. In one case, follow-up assessment of teaching evaluations one year after the

workshop indicates that at least half of the participants experienced improvement in their student ratings.[3] Anecdotal evidence, in the form of teaching awards received by participants, also indicates improvement.[3] In one study, a participant examined his student ratings by semester, and found a general upward trend.[2]

The author of this paper was a participant in T^{4}E in 1998, and returned to the ExCEEd Teaching Workshop in 1999 and 2000 to assist in running the workshop. In order to provide a specific comparison of how the workshop has enhanced his teaching skills, this paper provides an analysis of his student evaluations for the same course taught before attending the workshop and after.

2. Teaching Methodology

Various aspects of the T^{4}E model have been described elsewhere.[1-3] Here we provide only a brief description of some of the key points, highlighting aspects that are unique to a large research university setting. The overarching attitude embodied in this model (as well as other instructional models) can be summarized as follows:

Teaching is about student learning, not providing information.

In some ways this statement is obvious, but in others it is counterintuitive. How can students learn if you do not provide them information? Clearly, the content must be provided to the students if they are to learn it. However, the focus of a course should not be on providing as much information as can possibly fit, but rather on ensuring that the students learn the key information. Thus, the model is student-centered. With this attitude in mind, the following elements are an essential part of a course.

Communicating Expectations

This involves two areas, how grades are assigned and what content the students should learn. With regards to grades, it is important to have a clear scheme for assigning grades, and to communicate that scheme with the students. Without this communication, instructors run the risk as being perceived as "unfair" by the students, a characterization that can easily destroy the morale of a classroom.

With regard to content, the most effective means to communicate expectations is through the use of well-planned lesson objectives.[8] The author typically provides one to five objectives per lesson, although occasionally objectives may encompass more than one lesson. A variety of means exist to communicate objectives, even in classrooms with limited board space. These include posting them on the course webpage and distributing handouts in class. The author places them on large (2' x 2.5') Post-It® Notes before class, and then puts the Post-It® Note on a side wall of the classroom. This approach has several benefits: it saves board space; it saves time at the beginning of class; and the objectives are available to refer to during the class period.

Structured Content

Organizing the course content in a structured manner allows students to easily follow the development of ideas and to see connections between ideas. The process of creating a structured lesson follows these steps:

- Identification of the lesson topic. Typically, one major topic is identified for each lesson.
- Identification of lesson objectives. The objectives should be identified first, so that the lesson content focuses on what the students are expected to accomplish. Additionally, writing of objectives at different levels of Bloom's taxonomy[8] allows higher order thinking (or "independent thinking", see next section) to be utilized.
- Preparation of a lesson outline. The outline lays out the general order and hierarchy of the presentation.
- Preparation of board notes. Board notes are a specific technique utilized in the T^4E and ExCEEd workshops, and have been described previously.[1,2] Briefly, board notes lay out on a piece of paper exactly how material will be placed on the chalkboard during the classroom presentation. The board notes can also provide additional information for the instructor, as well as indications of demonstrations and questions (see below) that will be utilized. Use of color on the board notes, to indicate the use of colored chalk during class, can help to illustrate the hierarchy of ideas and clarify drawings.

This process may seem time-consuming, but in the author's experience it is actually time-saving in the long run. Prior to using this technique, considerable amount of time was spent immediately before each lesson deciding how material should be presented, making decisions on what should be put on the board and what should just be stated without writing down. While it does take some time to go through the process to create the board notes, once the notes are created it does not take any additional time to plan the classroom presentation. This can be particularly important at a research university, where there are many other demands on a faculty member's time.

Engaging Presentation

Even the best planned lesson can fail if it is delivered in a way that fails to engage the students. Lowman discusses the college classroom as a dramatic arena and describes the role of emotion in engaging students.[9] As a practical matter, the most important quality an instructor can display is enthusiasm for the subject. Use of voice, varying pitch and volume, helps to keep the students' attention.[10] The use of colored chalk, as described above, also contributes to an engaging presentation.

Three other specific techniques used by the author deserve to be discussed. First is the use of questions, by the instructor to the students, during the class. The role of these questions is to keep the students actively involved in the lesson, so they are not simply passive observers. Questions can be used to remind students about material already covered, as a means to test prior knowledge, or to get students to speculate about concepts not yet covered. The specific

questioning techniques used have been describe elsewhere.[2] The most common one is to ask a question, pause, and then call on a particular student. The pause forces all students to think about the answer, while calling on an individual student allows the instructor to make sure all students stay involved. In some cases the instructor may want to call on a particular student, perhaps the class "expert", in order to get the correct answer, or perhaps give an easy question to a struggling student to boost confidence. In typical large classes it is certainly not feasible to call on all students in every class. However, with careful attention it is possible to be sure that questions are spread evenly across the class over the course of a few lessons. Instructor responses to questions must always be positive, even to incorrect answers, since the goal of the questions is to enhance learning, not as evaluation.

Another important aspect of presentation is the use of demonstrations. Demonstrations can provide a means to break up the lesson and give a visual representation of abstract concepts. The author typically tries to have at least one demonstration per week, and the demonstration often requires student involvement. The author has found that students often remember the demonstration better than the concept it refers to, and he can remind students of the concept by reference to the demonstration.

More recently, the author has implemented elements of active learning into the classroom through specific problems that the students solve. Problems are handed out before class, and at the appropriate time the students are told to solve the problem, either on their own or in groups. These problems typically take two forms. Some problems are given so that students have an immediate opportunity to apply a concept or equation that has just been presented. Often misconceptions or areas requiring further clarification are immediately identified. In some cases, problems are given before the students have received all the information required to solve the problem. In these cases the students must use prior knowledge and their own intuition to solve the problem. The goal in this case is to make the students more receptive to the lesson content by sensitizing them to the need for that information. It should be noted that these problems were first implemented in the fall of 2000, and are not reflected in the assessment results given below.

Interpersonal Rapport

The three elements above all fall within the intellectual excitement dimension of Lowman's two dimensional model of effective teaching.[11] It is appropriate that the focus of the T^4E model be on this dimension, since Lowman found that intellectual excitement is slightly more important than interpersonal rapport for effective teaching. However, interpersonal rapport with students can not be ignored, as it is necessary to achieve the highest levels of teaching skill. There are several techniques that can be used to promote interpersonal rapport. The first is learning student names. This can be difficult in a large class, but the author has successfully used both data sheets, in which the students write down some information about themselves, and videotaping, for classes of up to 60 students. An immediate sense of rapport can be developed if the instructor can learn at least a majority of names using a videotape by the second class meeting. The questioning techniques described above also contribute to rapport, since it provides a means of interaction between student and instructor in the classroom. Talking to students one on one

outside of the context of specific lesson material conveys a sense that the you care about the students. This is where data sheets can be helpful, as they can provide some information on student interests.

In addition, the author recently began playing music at the beginning and end of every class. Music is chosen that relates to the lesson topic of the day, either by choosing a piece of music composed in the same year as some other event (e.g. Ohm's Law was discovered in the year of Beethoven's death) or by some common word (e.g. music by Led Zeppelin for discussing the lead-tin phase diagram). The reason for the choice of music is revealed at the appropriate point during the class, often in a humorous way. Comments from students indicate that they enjoy the music. However, the music was first implemented in fall of 1999, and thus is not reflected in the assessment results given below.

3. Assessment

The author taught the same course in both the spring semester of 1997 and the spring semester of 1999. Thus, comparison of student ratings from those two semesters provides a means to determine whether or not attending the workshop had an impact on teaching effectiveness. The student ratings utilized are for a standard end of semester evaluation administered for all courses taught at the University of Florida. These evaluations are used primarily to evaluate the instructor's performance with regards to tenure and promotion decisions. The results are also published on a webpage, and may be used by students to assist in course selection. Other uses are at the discretion of individual programs, and may include selection of instructors to teach particular courses and identification of instructors who should participate in faculty development activities.

The ratings being used for this paper come from an introductory materials science course required of many engineering students. Although nominally it is a junior level course, students range from sophomores to fifth year seniors. The data presented are for single sections in each semester. In order to analyze whether there was an improvement in student ratings, a t-test was applied to each of 27 questions on the standard end of semester evaluation form. Ratings are made on a scale from 1 to 5. Table 1 provides a shortened version of the questions, the ratings for the two semesters, and an indication of whether the ratings for each question are statistically different ($P<0.01$). The number of respondents was 37 for the pre-T^4E data and 31 for the post-T^4E data, reflecting a response rate of 80% and 84%, respectively. Note that Table 1 is not in the same order as the questions appear on the evaluation form. They have been reordered in order to group questions relating to similar issues. The groupings are indicated by double lines in the table.

The first thing to note about Table 1 are the values pre-T^4E. Although these ratings appear to be good, and would not have precluded a positive tenure decision, they were in fact lower than both departmental- and college-wide averages. For example, on the key question, "Overall I rate this instructor as…" the instructor received 3.86, the departmental average was 4.13, and the college

Table 1. Student ratings.

Question	Rating pre-T^{4}E	Rating post-T^{4}E	Statistically different? (P<0.01)
Description of objectives.	4.05	4.71	Yes
Communication of information.	3.95	4.77	Yes
Syllabus followed?	3.76	4.47	Yes
Expresses expectations for performance.	3.86	4.16	No
Availability outside of class.	3.95	4.42	No
Respect and concern for students.	4.11	4.39	No
Teaching methods.	3.68	4.81	Yes
Stimulation of interest.	3.84	4.63	Yes
Facilitation of learning.	3.78	4.52	Yes
Instructor enthusiasm.	4.24	4.77	Yes
Encourages independent thinking.	3.65	4.81	Yes
Instructor's knowledge.	4.27	4.81	Yes
Basics were covered.	3.97	4.48	Yes
Practical applications were provided.	3.76	4.52	Yes
My learning experience.	3.65	4.45	Yes
Value of course.	3.92	4.52	Yes
Overall I rate this instructor as…	3.86	4.71	Yes
Assignments.	3.59	3.90	No
Testing.	3.54	4.06	No
Timeliness of grading.	4.14	4.52	No
Fairness of grading.	3.73	3.84	No
Meeting on time.	4.22	4.65	No
Ending on time.	4.03	4.58	Yes
Course syllabus.	3.89	4.03	No
Text.	3.27	3.77	No
Text followed?	3.84	3.77	No
Instructor's attendance.	4.51	4.42	No

average was 3.95. In comparison, post-T^{4}E the ratings are in general higher than both departmental and college averages. Again, on the question of overall rating, the instructor received 4.71, the departmental average was 4.01, and the college average was 3.95. (See note in Table 2 for sample sizes.) While these are averages across many different courses, the result indicates that the author has significantly improved his performance with respect to his peers, going from below average to above average as a result of utilizing the T^{4}E model.

Comparison of ratings for each question in Table 1 shows that ratings either increased or stayed the same post-T^{4}E. In no case did the ratings decrease. In order to provide more detail on specific areas of improvement, the evaluation questions are divided into several categories, roughly corresponding with specific aspects of teaching. The first group is related to communication, the second deals with interpersonal rapport, the third deals with aspects of classroom presentation (including both structured content and engaging presentation, as described in the previous section), the fourth deals with students' overall feelings regarding the course and instructor, the fifth deals with the assignments, and the last deals with some mechanics of the course. Improvements in ratings are specifically seen in the areas of communication, classroom presentation, and overall feelings, while no improvement is seen for assignments and course mechanics. This is not surprising, since the focus of T4E is on those areas which saw improvement. In fact, the largest improvements (greater than one point) were for the questions on "Teaching methods" and "Encourages independent thinking", which fall into specific areas targeted by the T^{4}E model.

Table 2. Ratings for questions related to interpersonal rapport.

	Question	Instructor*	Department*	College*
Pre-T^{4}E	Availability	3.95	4.06	3.94
	Respect and concern	4.11	4.19	4.05
Post-T^{4}E	Availability	4.42	4.06	3.98
	Respect and concern	4.39	4.13	4.04

*Sample sizes are: Instructor 37 pre-T4E and 31 post-T4E; Department 511 pre-T4E and 494 post-T4E; College 7833 pre-T4E and 8631 post-T4E.

It is somewhat surprising that there is no statistically significant improvement on the questions dealing with interpersonal rapport. After attending the workshop the author did implement all of the strategies given in the previous section (e.g. specific strategies to learn students' names, questioning techniques in class, etc.). It is possible that he was already operating at a fairly high level of interpersonal rapport on Lowman's two dimensional model, and that potential areas of improvement were primarily along the intellectual excitement dimension. This appears to be partly supported by student written comments from the pre-T^{4}E evaluations, which include comments such as, "He wanted to learn our names and talk with us on a personal level," and, "He was very easy to talk to and always there for help." Comparison of the author's ratings for these two questions to departmental and college averages (Table 2) shows that students rated him comparable to his peers pre-T^{4}E, and slightly above (although probably not by a statistically significant amount) post-T^{4}E. Overall, then, it appears that the author was performing slightly

better than other areas on interpersonal rapport pre-T^4E, but he was not able to match the improvement in those other areas post-T^4E.

4. Conclusions

Student ratings clearly show that the T^4E model was effective at improving the author's teaching. Additional anecdotal evidence supports these conclusions, in the form of student comments to the author, referrals by students for their peers to take his classes, and two recent teaching awards from his peers. From the author's perspective, the T^4E model is effective because it provides specific, concrete steps that an instructor can take, while still allowing flexibility for individual teaching styles and further development. Nevertheless, it is difficult to make any general conclusions given the limited data available. For example, analysis of additional sections of the author's classes would be useful to determine whether the lack of improvement in interpersonal rapport was an anomaly or is consistent in all semesters. Expansion of the data set to include other instructors is also necessary to assess the general effectiveness of this model.

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