Successful Application of Active Learning Techniques to Introductory Microbiology

ELIZABETH A. HOFFMAN*

Ashland Community College, Ashland, Kentucky 41101

While the traditional lecture format may be a successful way to teach microbiology to both medical and nursing students, it was not an effective means of learning for many prenursing and preprofessional students enrolled in either of the introductory microbiology courses at Ashland Community College, an open enrollment institution. The structure of both Medical Microbiology and Principles of Microbiology was redesigned to allow students to address the material in an active manner. Daily quizzes, student group discussions, scrapbooks, lab project presentations and papers, and extra credit projects were all added in order to allow students maximum exposure to the course material in a manner compatible with various methods of learning. Student knowledge, course evaluations, and student success rates have all improved with the active learning format.

A number of educators (4, 12, 13, 18, 27, 28) have expressed belief that students do not all learn in the same manner. Gardner (12, 13) has proposed the theory of Multiple Intelligences to describe the different manners by which people learn. While the linguistic and logical intelligences have traditionally been addressed in the college classroom, many students achieve better mastery of the material when it is presented in a manner that addresses either their kinesthetic, spatial, musical, interpersonal, or intrapersonal intelligences. Millis and Cottell (22) suggest that students learn best when the material is presented in cooperative learning situations, with the instructor serving as a learning facilitator. The Seven Principles for Good Practices in Undergraduate Education (11) call for student-faculty contact with cooperation among students and active learning. Instructors need to allow students time on task with prompt feedback while communicating high expectations and respecting their diverse talents and ways of learning. Davis (6) also believes that active student participation, in conjunction with high expectations, can lead to student success when the students are presented with achievable goals. In addition, Wagschal and Wagschal (30) hold that adults learn better through dialogue than lecture and when they can tie personal experience to the subject matter.

Although many educators and scientists (2, 16, 23, 24, 25) have called for a reform in the way science is taught in the United States, very little information is available as to the effects of change on the ability of the students to learn the subject matter. Numerous instructors have suggested that both active learning (1, 5, 8, 9, 15, 17, 19, 21) and recognition of learning styles (3, 10) can be applied to biology courses, but little data has been available to support the effects of active learning on the part of the students. As an instructor of both medical and nursing students and students seeking admission to nursing and allied health programs, it became apparent to me that students studying microbiology did not all approach the material in the same manner. Virtually all of the medical students successfully completed the

course when the material was presented in a lecture format. At Ashland Community College, 89% of 147 summer school students in my introductory microbiology courses achieved at least a C over a period of 6 years. Although this was somewhat different from what I had experienced with medical students, it did not suggest a need to change the manner in which the material was presented. A stark contrast occurred during my first semester of teaching students not already affiliated with the nursing program. In the spring semester of 1995, I taught one section of Medical Microbiology to students seeking admission to the nursing program and one section of Principles of Microbiology. I used the same lecture materials, lab experiments, and exam formats as I had during the summer sessions. In this case, only 44% of 62 students successfully completed the courses. This large discrepancy led me to investigate a means of achieving student success for the general population of students taking the two courses. While Ashland Community College (mission statement [<http://www.ashlandcc.org>]) is an open enrollment institution, it fosters the development of the skills needed to achieve academic success by all students, regardless of academic background. My hypothesis was that college sophomores would be successful in microbiology if the material were presented in a nontraditional manner. The courses were restructured to allow students to address the material in a more active manner. Various activities were designed to incorporate at least one of the Multiple Intelligences or the Seven Principles for Undergraduate Education. The students were informed that the goal of the course was to have them become fluent in the language of microbiology so that they would be able to utilize both the written and spoken words and, most importantly, the thought processes of a microbiologist. Formal lectures would only be presented to "fill in the gaps" in student learning. Classroom activities and assessments were designed so that the final grade was a determination of student-centered learning.

ACTIVE LEARNING COMPONENTS

The various assessment components are found in Table 1. Most components were adaptations of activities that have been described by other instructors who are listed in the ac-

*Corresponding author. Mailing address: Ashland Community College, 1400 College Dr., Ashland, KY 41101. Phone: (606) 326-2067. Fax: (606) 326-2186. E-mail: elizabeth.hoffman@kctcs.net.

TABLE 1. Grade determination sheet from a class syllabus

Medical Microbiology grade determination sheet		
	Possible points	Actual points
Exam 1	100	_____
Exam 2	100	_____
Exam 3	100	_____
Exam 4	100	_____
Bluebooks (avg)	100	_____
Scrapbook	50	_____
Lab reports (avg)	100	_____
Group projects:		
Presentation	25	_____
Written report	25	_____
Peer evaluation	25	_____
Total	725	_____
Final avg = Total (_____) x 100 = _____ %		
	725	

knowledgments.

Daily bluebook quizzes. The major difference from a lecture format was the preparation by students for daily quizzes that were recorded in a single bluebook over the course of the entire semester. The students were quizzed on the material before it was to be covered during class discussion. Study guides that covered the material to be mastered for an entire exam were provided. The study guides contained the goals, objectives, and key words for each chapter. Reading assignments that covered one or more chapters were given prior to every class period. Students were encouraged to meet in study groups prior to class to review the answers to the objectives that they had prepared individually ahead of time. The success of the study group meetings could usually be judged by the reaction of the group members upon seeing the questions of the day. Five minutes were allotted at the start of each class period to answer several short written questions that were based on the assigned objectives. For example, questions that would meet the objective to compare and contrast procaryotic cells would be: "briefly describe one similarity between procaryotic and eucaryotic cells" or "briefly describe one difference between procaryotic and eucaryotic cells." Questions that would meet the objective to know the diseases caused by specific organisms would include: "list three organisms that may cause food poisoning" or "name one similarity between diseases caused by streptococcal organisms and diseases caused by staphylococcal organisms." Three or four questions were asked for a total of five items that would need to be recalled

by the students. The questions were all general enough that many different answers were possible. Each student was limited to no more than one-half of a page in a bluebook for all the answers for a class period. Students were provided with immediate feedback to their answers during the ensuing class discussions. Graded books were returned to the students at the start of the following class for use in the class period. There were no make-up bluebook quizzes, but the four lowest grades were discarded prior to averaging the quizzes at the end of the semester.

Cooperative learning activities. Students were organized into groups of four. They discussed material daily in these groups, guided by individual worksheets to facilitate active learning. The worksheets consisted of tables with various missing components, lists of similarities and differences between definitions, graphs that needed completion, Venn diagrams, and case studies. Students were to complete the worksheets by consulting with the other group members but not by consulting their notes or the textbook. A sample Venn diagram with typical student answers is provided in Fig. 1. Other Venn diagrams were used to stimulate discussion about the similarities and differences of macrophages and neutrophils, humoral and cell-mediated immunity, and even key features of the first, second, and third lines of immune defense. Worksheets were used to map the concepts of aerobic respiration and fermentation, DNA replication along with transcription and translation, and the large amount of terminology associated with epidemiology.

The entire second half of the course was devoted to the study of pathogenic organisms that were covered by a total of four case studies (14) in each class period. Most of the case studies were based on actual cases that have been described in *Morbidity and Mortality Weekly Report*. Cases included such reports as botulism in an individual who consumed stew that had been left at room temperature for three days, rabies in an individual who had explored the mouth of a dead bat with his fingers, and hepatitis E contracted from drinking margaritas with crushed ice. A brief paragraph introduced the patient's history, symptoms, and lab results. Students were permitted to consult their text, flashcards, medical dictionary, and notes prepared at home to diagnose the case. Each student in the group was limited to consulting one reference in order to encourage discussion of the ensuing questions concerning the causative agent of the disease and the methods of its control and prevention.

A typical class would contain five or six discussion groups, so I would visit each group several times before the activity was completed to ensure that the students both kept on the topic and completed the worksheet with appropriate answers. After a sufficient amount of time had passed for the groups to complete the activity, I would call on random members of every group to share with the class a part of the worksheet of the student's choice until all the material on the worksheet was reviewed. A typical class period covered three or four activities or case studies in seventy-five minutes.

Scrapbooks. Each student was required to keep a scrap-

Complete the Following Diagram to Compare and Contrast Cells

FIG. 1. Sample student worksheet.

book of relevant news articles, pamphlets, junk mail, etc., which applied to microbiology and were encountered during the semester. Original copies of all materials were to be attached to the pages of the scrapbook in chronological order. Undated material could be placed in an appendix in the back of the book. Corrections were to be made if the material in the article was inaccurate or incomplete. For example, a bacterium may be referred to in the article as a virus, or a fungus may be described as a bug. A minimum of three articles was to be included from each week of the semester. At least one of the articles each week was to be from the Internet. Points were deducted for each period of seven days in which no articles were included in the book. Points were also deducted for each piece of incorrect information that was not corrected by the student. Scrapbooks that had received full points and lists of topics of articles from previous semesters were on display in the classroom for the students.

Group projects. Each group of students designed and implemented a lab project to isolate and identify environmental organisms from a chosen area using the techniques learned in approximately the first two-thirds of the semester. Projects have included isolating and identifying organisms from such diverse objects as doorknobs, money, cutting boards, fingernails, aluminum cans, and pens. A check sheet was provided to each group to ensure that guidelines were met for a proper research project. All experiments were to include an isolation of organisms, establishment of pure cultures, and detailed attempt to identify each organism. Identification was made on the basis of Gram morphology, growth patterns on differential media, oxygen requirements, spore-forming abilities, motility, temperature requirements, presence of certain enzymes, and ability to withstand temperature, disinfectants, antibiotics, ultraviolet light, etc. Students were given guidance as to the initial isolation of the organisms and preparation of Gram stains, but all additional experiments were designed by the students in order to identify the properties of the particular organisms that they had

isolated. They were required to identify the genus and, if possible in our lab, the species. I explained that it may not always be possible to identify the organisms to species level, but that they must explain what further tests could be conducted and how the results would identify the species. Group presentations of no more than twenty minutes were given on the last day of class. The presentations included the rationale for the particular project, the possible organisms that could be found in the chosen site, analysis of the data that led to the identification of the organisms, any diseases that could be caused by the organisms, and recommendations for control and/or prevention of the diseases. The students were encouraged to use their imaginations as well as their analytical skills during their presentations. Sample presentations were available for viewing by the students. Some students chose to videotape their presentations that included skits with appropriate musical accompaniment. Others included the entire class in audience participation. Many groups took photographs of their work during the project and used the pictures as visuals during the presentations. Individual written reports, of no more than ten typed pages, were due at the same time as the presentations. The reports were each student's personal analysis of the entire project. In addition, each group member was evaluated for participation in the project by all other members of the group. Each student divided the total possible points among the other members of the group. They were not allowed to award any points to themselves. The written evaluations were performed in class prior to the group presentation and without consultation with other members of the group.

Exams. There were four lecture exams. Multiple choice and matching style questions constituted 80% of the exam. Examples of multiple-choice questions are:

1. A difference between procaryotic and eucaryotic organisms is:
 - A. the presence of ribosomes in the cytoplasm.
 - B. the presence of mitochondria for energy

- production.
- the presence of a cell membrane.
 - DNA as genetic material.
 - cytoplasm where metabolic reactions occur.
2. Which of the following is associated with a *Staphylococcus aureus* infection?
- food poisoning after eating undercooked hamburgers
 - nosocomial pneumonia following knee surgery
 - severe diarrhea after eating raw oysters
 - lung congestion with the production of scanty sputum
 - none of the above are true

The remainder of each exam consisted of fill-in-the-blank and short answer questions that were similar to the bluebook questions in that several different answers were possible. Examples of questions that could be answered on the basis of group discussions are: "one similarity between the processes of glycolysis and the TCA cycle is _____," "one difference between the first and second lines of immune defense is _____," and "an organism that may cause a zoonotic disease is _____." Other questions that required the development of application of knowledge include: "older bacterial cultures are needed to produce endospores because _____," "one reason why gram-negative cells would appear purple is _____," and "children with SCID cannot reject grafts because _____."

Extra credit projects. An extra credit project was assigned for each exam. The project was to be a group effort and each member of the group was to sign the project as an indication of participation. The project was worth a total of five extra points on the appropriate exam. A scoring rubric explained the point distribution for relevancy, accuracy, completeness, and use of imagination. The project was due the week before the exam in order to correct any inaccuracies that the students may have on the subject before the exam. The projects for the first two exams were designed to help explain topics that were particularly difficult for the students to grasp. Projects for exam 1 have included three-dimensional models of procaryotic protein synthesis. Projects for exam 2 have included models of macrophage, T cell, and B cell interactions prior to antibody synthesis. Students have used such diverse items as construction paper, candies, sheet metal, marbles, magnetic-backed paper, and children's action figures in their models. Projects for exams 3 and 4 were case studies of diseases modeled on the cases studied in the course. Case studies were based on information from newspapers, scientific journals, and the Internet published in the last six months.

EVALUATION

The effectiveness of the course structure was evaluated both from the success of students in the courses and the satisfaction of the students with the various class activities. The microbiology courses that were offered in the spring semes-

ter of 1995 followed a traditional lecture format. Only 44% of 62 students in the Medical Microbiology and Principles of Biology classes were successful in the courses (Fig. 2). In contrast, over the period from fall semester of 1995 to spring semester of 1999, 81% of the 299 students were successful in the 16 class sections that incorporated active learning techniques. Student success ranged from a high of 97% in the spring of 1996 to a low of 68% in the spring of 1997, but in all semesters there was an increase over the 44% success rate in the spring of 1995. In addition, at least 75% of the students rated the study guides, daily quizzes, class discussions, case studies, and extra credit projects helpful in achieving mastery of the material. At least 60% of the students also evaluated the study groups, lab group projects, presentations, and individual papers and scrapbooks as being helpful for learning the material for the course. Students were encouraged to anonymously evaluate the course in order to suggest modifications to the format for future classes. Negative criticism included such statements as: "I believe lectures should be held in classroom settings" and "a lot of material to absorb in a small amount of time if you have jobs, family, etc." and "I think you expect too much out of one class." Positive evaluations from three students included such statements as:

I really enjoyed this class. The case studies, class discussions, and study groups were great. I learned so much more in this class than I usually do. I struggled so hard in Anatomy I & II—but the way you had things set up this semester made it easier to learn. You made it easy for me to participate in class discussions—I usually just sit there & don't say a thing. Participating in those class discussions helped me a lot in learning the material.

FIG. 2. Student success as determined by the percentage of students achieving a grade of A, B, or C in Medical Microbiology or Principles of Microbiology out of total students enrolled in the course on the last day to add the class. Data collected in lecture classes was determined in spring semester (S) of 1995. Data collected with active learning classes was determined during fall semester (F) of 1995 through spring semester of 1999.

I thought the different methods of learning the material made the class more interesting. I thought the bluebooks were a great way to make me read over the chapters. Otherwise I probably would have never read over the chapters until test time. I really enjoyed this class.

As an instructor you require a lot out of your students, but I don't mean for you to think of this negatively. I mean that it is positive. I have enjoyed this course tremendously and have learned so much! If I were you, I wouldn't change a thing with your course. I have never worked so hard in any course but then again I have never learned so much. Micro is interesting & fun & frustrating.

DISCUSSION

The low rate of student success in microbiology courses (Fig. 2) was a motivating factor in changing the course structure from that of lecturing to an active learning format. Other educators have expressed similar motivation in changing the manner in which the material in their discipline is presented to students. Some instructors (9, 15, 21) of large biology lecture classes have found that while students in general have felt more confident in their ability to understand science, there was little difference in their scores on traditional exams. Similar results were found by Lunsford and Herzog (20) with an anatomy and physiology course. Others have had more positive outcomes. Anderson (1) reported a positive change in the grade distribution of an environmental course for nonscience majors. Trottier (29) found success in some sections of pharmacology with cooperative learning. Dougherty et al. (7) believe that active learning increased both performance, retention, and attitudes in students in large general chemistry lecture classes, and Paulson (26) reported similar results in organic chemistry lecture classes. Buxeda and Moore (3) have also described success in a microbiology class in which activities were designed to address the learning styles of the students.

Various educators have suggested that students achieved better mastery of course content when exposed to the material in a variety of ways. The recognition of the possibility of as many as sixteen different learning styles (18) motivated me to change to a class structure where the student was made more responsible for mastery of the course material while addressing the material from a number of different aspects. The key component in the class structure was the daily quizzes that were recorded by each student in a single bluebook over the course of the semester. The questions were designed to have many possible answers so that the students would be able to get full credit by carefully preparing for class. This type of question provided the students with Davis' (6) suggestion of an achievable goal of success on the quiz in spite of the high expectation of reading and assimilating the material prior to class discussion. Personal preparation for class involved both the linguistic and logical intelligences as described by Gardner (13), while the participation in study groups involved the cooperation of students participating in active learning as proposed by Gamson (11). By the end of the semester, Gardner's intrapersonal intelligence was utilized by most of the students to reveal the value of coming to class prepared for the topic of the day. A review of the semester's accomplishments fostered a sense of achievement of the large body of knowledge accumulated in the single bluebook containing all the daily quizzes (Table 2).

The material for class discussion provided prompt feedback for the daily quizzes as suggested by Gamson (11). All members were expected to contribute to the group discussion and to record the information on their individual worksheets. In that way, students acquired information they may have not garnered themselves from the reading assignment. When all the groups had finished the worksheets, an individual from each group was randomly invited to describe an answer that had been formulated by the entire group. No one student was responsible for a particular answer, yet each student was empowered by the answer of the entire group.

TABLE 2. Student satisfaction with active learning techniques^a

Active learning technique	Student response		
	Helpful	Detrimental	No opinion
Study guides	86	6	8
Daily quizzes	85	9	6
Class discussions (first half semester)	88	6	6
Case studies	86	6	8
Extra credit projects	78	12	10
Study groups	69	16	15
Lab group projects	66	17	17
Group presentations	65	18	17
Individual papers	66	19	15
Scrapbooks	71	12	17

^a As determined by the percentage of students responding in a survey conducted at the time of the final exam during eight semesters from fall 1995 through spring 1999 ($n = 299$).

By hearing from members of all the groups, the topic was covered as completely as if a lecture had been presented. While some of the many details that might have been covered in lecture were omitted, the students had more time to absorb the important aspects of the topics. In addition, they utilized both intrapersonal and interpersonal communication skills, linguistic and logical skills, and kinesthetics as described by Gardner (13) while still studying the major concepts of an introductory microbiology course (8). The students absorbed the material by immediate use of learning in a cooperative manner as proposed by Gamson (11). Moreover, many of the nontraditional students with experience in various health care positions were able to contribute valuable insight into group discussions of case studies beyond what was presented in the textbook as suggested by Wagschal and Wagschal (30).

The preparation of a scrapbook was designed both to allow the students to express their own learning styles (18) and to foster in them an appreciation for the need for continuing education in the ever changing field of microbiology. Students who may have entered the course with limited Internet skills become empowered both with the use of the Internet as a learning tool and the development of life-long learning skills. The scrapbook also served as an assessment of the student's ability to critically evaluate information about microbiology that was published by the news media.

The lab group project was both an alternative to practical exams and an area where students were allowed to address their own individualities in the choice of both the topic for the project and the manner in which the presentations were conducted. Check sheets and a scoring rubric were used to guide the content, but the students were free to use their imaginations (13) for the source of the organisms to be studied. The students learned that they could have fun while using the technical and analytical skills acquired in class to isolate and identify organisms from an environmental source of their own choice. The group presentation and peer evaluations demonstrated the effectiveness of their interpersonal communication (13) and cooperative learning (11), while the paper assessed each student's critical thinking skills.

The four traditional exams contributed about half the points in determining the final grade (Table 1). Multiple-choice questions constituted at least half of the possible exam points, since most students are assessed by objective questions on their licensure or admissions exams. The questions were formatted to assess the critical thinking skills fostered by group discussions of worksheets and case studies. Students performed as well on the exams as previous students had on exams that required few, if any, critical thinking skills. Each exam also had an extra credit project that required group participation. Extra credit projects contributed to the students' learning by addressing their various learning styles (18) and multiple intelligences (13).

The role of the instructor as an active learning facilitator, as described by Millis and Cottell (22), is different from that of a lecturer. Considerable time is needed to grade the multifaceted class assignments. It is also more difficult to

ensure that the course content will be covered in each class section when the students are leading the class discussions. However, there is a two-fold reward for allowing the students to experience an active learning environment. The first reward is in the number of students that are successful in the course (Fig. 2). The most important reward is the development of critical thinking and life-long learning skills that are carried out of the classroom and into the students' further education (T. Elswick [Ashland Community College, Kentucky], personal communication) and careers.

ACKNOWLEDGMENTS

Many of the class activities are adaptations of ideas presented by colleagues at workshops on undergraduate education. I extend thanks to: Virginia J. Anderson, Towson State University, Towson, Md. for Venn diagrams; Cathy D. Hunt, Henderson Community College, Henderson, Ky. for case studies and group discussions; Mary A. McMurray, Henderson Community College, Henderson, Ky. for classroom activities; Larry K. Michaelson, University of Oklahoma, Norman, Okla. for peer evaluation; Dennis Oppenheim, Quinnipiac College, Hamden, Conn. for bluebook quizzes; Robin Patterson, Butler County Community College, Butler, Pa. for group projects; and Joanna Verran, Manchester Metropolitan University, Manchester, England for scrapbooks.

REFERENCES

1. **Anderson, E. J.** 1997. Active learning in the lecture hall. *J. Coll. Sci. Teaching* **26**:428–429.
2. **Boyer, E.L.** 1986. *College: the undergraduate experience in America*. Carnegie Foundation for the Advancement of Teaching, Princeton, N.J.
3. **Buxeda, R. J., and D. A. Moore.** 1999. Using learning-styles data to design a microbiology course. *J. Coll. Sci. Teaching* **29**:159–164.
4. **Claxton, C. S., and P. H. Murrell.** 1987. Learning styles: implications for improving education practices. ASHE-ERIC higher education report, no. 4. Association for the Study of Higher Education, Washington, D.C.
5. **Colosi, J. C., and C. R. Zales.** 1998. Jigsaw cooperative learning improves biology lab courses. *BioSci.* **48**:118–124.
6. **Davis, B. B.** 1993. *Tool for teaching*. Jossey-Bass Publishers, Inc., San Francisco, Calif.
7. **Dougherty, R. C. et al.** 1995. Cooperative learning and enhanced communication. *J. Chem. Educ.* **72**:793–797.
8. **Douthright, J.** 1994. Undergraduate microbiology curriculum recommendations. *ASM News* **60**:460–461.
9. **Ebert-May, D., C. Brewer, and S. Allred.** 1997. Innovation in large lectures—teaching for active learning. *BioSci.* **47**:601–607.
10. **Felder, R. M.** 1993. Reaching the second tier—learning and teaching styles in college science education. *J. Coll. Sci. Teaching* **23**:286–290.
11. **Gamson, Z. F.** 1991. A brief history of the seven principles for good practice in undergraduate education, p. 5–12. In A. W. Chickering and Z. F. Gamson (ed.), *Applying the seven principles for good practice in undergraduate education*. Jossey-Bass Pub-

lishers, Inc., San Francisco, Calif.

12. **Gardner, H.** 1993. Frames of mind, the theory of multiple intelligences. Basic Books, New York, N.Y.

13. **Gardner, H.** 1999. Intelligence reframed, multiple intelligences for the 21st century. Basic Books, New York, N.Y.

14. **Gilligan, P. H., D. S. Shapiro, and M. L. Smiley.** 1992. Cases in medical microbiology and infectious diseases. American Society for Microbiology, Washington, D.C.

15. **Goodwin, L., J. E. Miller, and R. D. Cheetham.** 1991. Teaching freshmen to think—does active learning work? *BioSci.* **41**:719–722.

16. **Hartman, E. M., Jr., and N. Dubowsky.** 1995. The nature and process of science: a goal-focused approach to teaching science literacy. *J. Coll. Sci. Teaching* **24**:92–95.

17. **Jensen, M.** 2000. Each year I teach less and less. *J. Coll. Sci. Teaching* **30**:206–208.

18. **Lawrence, G.** 1997. Looking at type and learning styles. Center for Applications of Psychological Type, Inc., Gainesville, Fla.

19. **Lord, T.** 1998. Cooperative learning that really works in biology teaching. *The Am. Biol. Teacher* **60**:580–588.

20. **Lunsford, B. E., and M. J. R. Herzog.** 1997. Active learning in anatomy & physiology. *The Am. Biol. Teacher* **59**:80–84.

21. **Miller, J. E., and R. D. Cheetham.** 1990. Teaching freshmen to think—active learning in introductory biology. *BioSci.* **40**:388–391.

22. **Millis, B. J., and P. G. Cottell, Jr.** 1998. Cooperative learning for higher education faculty. American Council on Education/Oryx Press, Phoenix, Ariz.

23. **National Institute of Education.** 1984. Involvement in learning: realizing the potential of higher education. U.S. Government Printing Office, Washington, D.C.

24. **National Research Council.** 1996. National science education standards. National Academy Press, Washington, D.C.

25. **National Research Council.** 1996. From analysis to action: undergraduate education in science, mathematics, engineering, and technology. National Academy Press, Washington, D.C.

26. **Paulson, D. R.** 1999. Active learning and cooperative learning in the organic chemistry lecture class. *J. Chem. Educ.* **76**:1136–1140.

27. **Quenk, N. L.** 2000. Essentials of Myers-Briggs type indicator assessment. John Wiley & Sons, Inc., New York, N.Y.

28. **Stage, F. K., P. A. Muller, J. Kinzie, and A. Simmons.** 1998. Creating learning centered classrooms, what does learning theory have to say? ASHE-ERIC higher education report, vol. 26, no. 4. The George Washington University Graduate School of Education and Human Development, Washington, D.C.

29. **Trottier, R. W.** 1999. A peer-assisted learning system ('PALS') approach to teaching basic sciences. *Med. Teacher* **21**:43–47.

30. **Wagschal, K., and P. H. Wagschal.** 1995. Teaching adult learners, p. 235–248. In P. Seldin and Associates, Improved college teaching. Anker Publishing Company, Inc., Bolton, Mass.

Post Doctoral Scientists & Graduate Students.....

If you are interested in:

Learning About Microbiology **Career Opportunities**

Preparing a Successful **Grant Proposal**

Presenting a Powerful and Convincing **Speech**

Improving your **Teaching Skills**

then you should sign up for:

First Summer Institute in Preparation for Careers in Microbiology

University of Wisconsin, Madison Wisconsin

August 4 -10, 2001

<http://www.asmta.org/edusrc/edu52001.htm>

Fellowships-CareerInformation@asmta.org

202-942-9283

Sponsored by the ASM Board of Education and Training